Claims

1. A macromolecular reaction product comprising

(a) one or more

i) heterocyclic compounds substituted with one 3,5-di-hydrocarbyl-4-hydroxylbenzyl group; ii) heterocyclic compounds substituted with two 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iii) heterocyclic compounds substituted with three 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iv) heterocyclic compounds substituted with four 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups; or

v) heterocyclic compounds substituted with five 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups; and

(b) one or more methylene-bridged heterocyclic compounds substituted with one or more 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups,

wherein the methylene-bridge is between two heterocyclic groups, and

wherein said heterocyclic compounds are selected from the group consisting of pyrrole, imidazole, pyrazole, pyridine, pyrimidine, pyrazine, thiophene, 2-benzothiophene, dithiine, benzodithiine, indole, quinoline, oxazole, isoxazole, thiazole, and isothiazole, furan, 2-benzofuran, 1,4-dioxin, benzodioxin, optionally substituted by one or more hydroxy, mercapto, alkoxy, amino, monoalkylamino, dialkylamino, and/or C_{1-12} hydrocarbyl groups.

2. A macromolecular reaction product comprising

(a)

i) less than 10wt.% of one or more heterocyclic compounds substituted with one 3,5-di-hydrocarbyl-4-hydroxylbenzyl group;

ii) less than 25wt.% of one or more heterocyclic compounds substituted with two 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iii) greater than 15 wt.% of one or more heterocyclic compounds substituted with three 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

greater than 10 wt.% of at least one of iv) one or more heterocyclic compounds substituted with four 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups, v) one or more heterocyclic compounds substituted with five 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups, or combinations of iv) and v); and

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(b) one or more methylene-bridged heterocyclic compounds substituted with one or more 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups, wherein the methylene-bridge is between two heterocyclic groups,

wherein all wt.% are based on the total weight of the macromolecular reaction product, and wherein said heterocyclic compounds are selected from the group consisting of pyrrole, imidazole, pyrazole, pyridine, pyrimidine, pyrazine, thiophene, 2-benzothiophene, dithiine, benzodithiine, indole, quinoline, oxazole, isoxazole, thiazole, and isothiazole, furan, 2-benzofuran, 1,4-dioxin, benzodioxin, optionally substituted by one or more hydroxy, mercapto, alkoxy, amino, monoalkylamino, dialkylamino, and/or C_{1-12} hydrocarbyl groups.

3. The macromolecular reaction product according to claim 2 wherein said macromolecular reaction product comprises

(a)

i) less than 5 wt.%, of one or more heterocyclic compounds substituted with one 3,5-di-hydrocarbyl-4-hydroxylbenzyl group,

ii) less than 15 wt.%, of one or more heterocyclic compounds substituted with two 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iii) in the range of from 15wt.% to 40 wt.% of one or more heterocyclic compounds substituted with three 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iv) in the range of from 10wt% to 70 wt.% of one or more heterocyclic compounds substituted with four 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

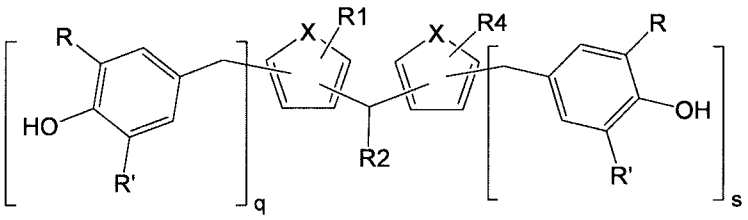
v) in the range of from 5wt% to 45 wt.% of one or more heterocyclic compounds substituted with five 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups; and

(b) in the range of from 1wt% to 15 wt.% of one or more methylene-bridged heterocyclic compounds substituted with one or more 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups,

wherein all wt.% are based on the total weight of the macromolecular reaction product.

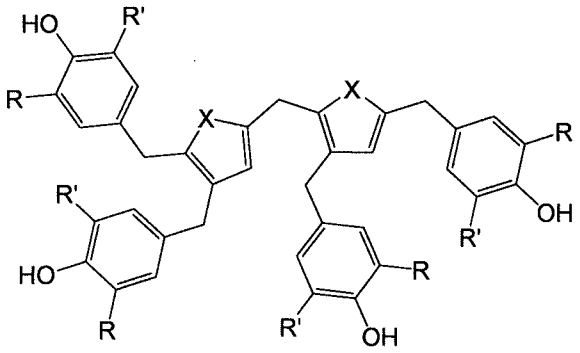
4. The macromolecular reaction product according to claim 2 wherein said macromolecular reaction product comprises one or more compounds represented by the following general

formula, Formula IV:



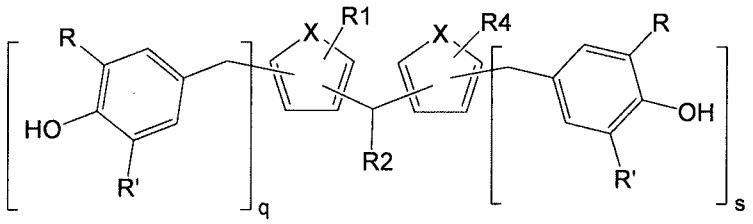
wherein each X is independently sulfur, oxygen, or nitrogen; R and R' are hydrocarbyl, and each R1 and R4 are independently hydrogen or hydrocarbyl; R2 is hydrogen, q and s are independently 1 or 2.

5. The macromolecular reaction product according to claim 2 wherein said macromolecular reaction product comprises one or more compounds represented by Formula V:



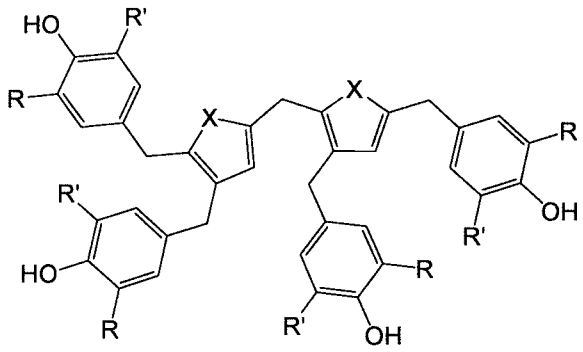
wherein each X is independently sulfur, oxygen, or nitrogen; and R and R' are hydrocarbyl.

6. The macromolecular reaction product according to claim 1 wherein said one or more methylene-bridged heterocyclic compounds substituted with one or more 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups are represented by Formula IV, Formula V, or Formula IV and Formula V:



IV

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V,

wherein

each X is independently sulfur, oxygen, or nitrogen;

R and R' are hydrocarbyl;

each R1 and R4 are independently hydrogen or hydrocarbyl;

R2 is hydrogen; and

q and s are independently 1 or 2.

7. A composition comprising:

a) one or more organic materials that are susceptible to oxidation in the presence of air or oxygen selected from at least one oil of lubricating viscosity selected from Group I, II, and III mineral oils, poly-alpha-olefins, synthetic esters, gas to liquid derived oils, bio-based oils, internal combustion engine oils, railroad and marine lubricants, natural gas engine oils, gas turbine oils, steam turbine oils, aviation turbine oils, rust and oxidation oils, hydraulic fluids, compressor fluids, slideway oils, quench oils, manual and automatic transmission fluids, gear oils, and greases;

b) an antioxidant product containing:

i) less than 10 wt.%, of one or more heterocyclic compounds substituted with one 3,5-di-hydrocarbyl-4-hydroxylbenzyl group;

ii) less than 20 wt.%, of one or more heterocyclic compounds substituted with two 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iii) in the range of from 15wt.% to 40 wt.% of one or more heterocyclic compounds substituted with three 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

iv) in the range of from 10wt% to 70 wt.% of one or more heterocyclic compounds substituted with four 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

v) in the range of from 5wt% to 45 wt.% of one or more heterocyclic compounds substituted with five 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups;

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vi) in the range of from 1wt% to 15 wt.% of one or more methylene-bridged heterocyclic compounds substituted with one or more 3,5-di-hydrocarbyl-4-hydroxylbenzyl groups, wherein the methylene-bridge is between two heterocyclic groups,

wherein all wt.% are based on the total weight of the macromolecular reaction product, and

wherein said heterocyclic compounds are selected from the group consisting of pyrrole, imidazole, pyrazole, pyridine, pyrimidine, pyrazine, thiophene, 2-benzothiophene, dithiine, benzodithiine, indole, quinoline, oxazole, isoxazole, thiazole, and isothiazole, furan, 2-benzofuran, 1,4-dioxin, benzodioxin, optionally substituted by one or more hydroxy, mercapto, alkoxy, amino, monoalkylamino, dialkylamino, and/or C_{1-12} hydrocarbyl groups; and

c) one or more dispersants, detergents, anti-wear additives, extreme pressure additives, corrosion inhibitors, rust inhibitors, friction modifiers, metal deactivators, lubricity agents, pour point depressants, antiknock agents, anti-icing agents, viscosity index modifiers, emulsifiers, demulsifiers, seal swell agents, solubilizing agents, antifoam agents, other antioxidants or stabilizers, diluents, solvents, carrier fluids, Zinc dialkyldithiophosphate, at least one conventional hindered phenolic antioxidant, at least one conventional alkylated diphenylamine antioxidant, at least one organomolybdenum compound, at least one alkylated diphenylamine and at least one organomolybdenum compound, at least one phosphorus-free anti-wear or extreme pressure additive, at least one molybdenum-containing or boron-containing dispersant, at least one organoboron compound, at least one organoboron compound and at least one conventional alkylated diphenylamine, at least one sulfurized antioxidant, EP (extreme pressure) additive or anti-wear additive, at least one conventional alkylated diphenylamine along with at least one (i) sulfurized antioxidant, (ii) EP additive, (iii) anti-wear additive, and (iv) organoboron compound.

8. A macromolecular reaction product of claim 1 formed by bringing together components comprising:

(A) a sterically hindered 4-alkoxymethyl-2,6-dihydrocarbylphenol or 4-hydroxymethyl-2,6-dihydrocarbylphenol;

(B) at least one heterocyclic compound which is a monocyclic or dicyclic compound wherein:

a) the monocyclic group of the monocyclic compound is fully conjugated and has heteroatom(s) in the fully conjugated ring thereof (i) one nitrogen atom, one sulfur atom, or one oxygen atom, (ii) one sulfur and one nitrogen atom, one sulfur and one oxygen atom, or one nitrogen and one oxygen atom, or (iii) two nitrogen atoms, two sulfur atoms, or two oxygen atoms, or

b) at least one of the cyclic groups of the dicyclic compound is fully conjugated and has heteroatom(s) in the fully conjugated ring thereof (i) one nitrogen atom, one sulfur atom, or one oxygen atom, (ii) one sulfur and one nitrogen atom, one sulfur and one oxygen atom, or one nitrogen and one oxygen atom, or (iii) two nitrogen atoms, or two sulfur atoms, or two oxygen atoms,

wherein said heterocyclic compound is selected from the group consisting of pyrrole, imidazole, pyrazole, pyridine, pyrimidine, pyrazine, thiophene, 2-benzothiophene, dithiine, benzodithiine, indole, quinoline, oxazole, isoxazole, thiazole, and isothiazole, furan, 2-benzofuran, 1,4-dioxin, benzodioxin, optionally substituted by one or more hydroxy, mercapto, alkoxy, amino, monoalkylamino, dialkylamino, and/or C_{1-12} hydrocarbyl groups;

(C) an alkylation catalyst, and

optionally, an organic solvent.

9. The macromolecular reaction product of claim 8, wherein said 4-alkoxymethyl-2,6-dihydrocarbylphenol or 4-hydroxymethyl-2,6-dihydrocarbylphenol is 4-hydroxymethyl-2-tert-butyl-6-methylphenol, 4-hydroxymethyl-2,6-di-tert-butylphenol, 4-methoxymethyl-2-tert-butyl-6-methylphenol or 4-methoxymethyl-2,6-di-tert-butylphenol.

10. The macromolecular reaction product of claim 8, wherein said heterocyclic compound is thiophene or furan.

11. The macromolecular reaction product of claim 8, wherein a molar ratio of (B) to (A) used in the reaction ranges from 1:1 to 1:10.

12. The macromolecular reaction product of claim 1, wherein said macromolecular reaction product is liquid at room temperatures or a solid that melts at less than 100 °C, and are capable of being dissolved in liquid hydrocarbon solvents.

13. The macromolecular reaction product of claim 2, wherein said macromolecular reaction product is liquid at room temperatures or a solid that melts at less than 100 °C.