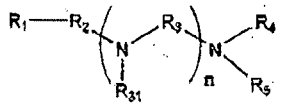
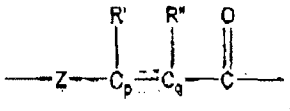
CLAIMS

1. A compound represented by the formula:



wherein R_1 is a branched or straight-chained C_{10}-C_{600} polypropylene or poly(ethylene-co-propylene) group;

R_2 is , wherein the carbonyl carbon connects to nitrogen, the bond between carbons Cp and Cq is either a single or double bond, wherein when the bond between carbons Cp and Cq is a single bond, a hydrogen is attached to each of Cp and Cq as required by valency; R' and R" are independently H or unsubstituted or substituted C_1-C_4 alkyl or C_1-C_4 alkenyl, and Z is a bond or unsubstituted or substituted C_1-C_4 alkylene;

R_3 is a C_1-C_{10} branched or straight chained alkylene group;

n is an integer from 1 to 10;

R_4 and R_5 are both independently selected from hydrogen and $-R_6$-R_7, wherein R_6 is defined the same as R_2 above, and R_7 is defined the same as R_1 above;

R_{31} is hydrogen or $-R_8$-R_9, wherein R_8 is defined the same as R_2 above, and R_9 is defined the same as R1 above, or R_8 and R_9 together are a C1-C10 branched or straight chained alkyl group optionally substituted with one or more amine groups;

and wherein the $-N(R_{31})$-R_3- repeat unit is optionally interrupted in one or more places by a heterocyclic or homocyclic cycloalkyl group

2. The compound of claim 1, wherein the polypropylene is atactic polypropylene, isotactic polypropylene, syndiotactic polypropylene.

3. The compound of claim 1, wherein the polypropylene is amorphous.

4. The compound of claim 1, wherein the polypropylene include isotactic or syndiotactic crystallizable units.

5. The compound of claim 1, wherein the polypropylene include meso diads constituting from about 30% to about 99.6% of the total diads of the polypropylene.

6. The compound of claim 1, wherein at least one of R_1, R_7, and R_9 has a number-averaged molecular weight of from 300 to 30000 g/mol.

7. The compound of claim 1, wherein at least one of R_1, R_7, and R_9 has a number-averaged molecular weight of from 500 to 5000 g/mol.

8. The compound of claim 1, wherein at least one of R_1, R_7, and R_9 comprises from 10 mole % to 50 mole % of ethylene units and from about 50 mole % to about 90 mole% propylene units.

9. The compound of claim 1, wherein R_1 is poly(ethylene-co-propylene), R_3 is $-CH_2CH2-$, R_3 is hydrogen, and R_4 and R_5 are both hydrogen.

10. The compound of claim 1, wherein R_2 is $-CH_2-CH_2-C(O)-$.

11. The compound of claim 1, wherein the nitrogen content in the additive is 1 wt% to 10 wt% based on the total weight of the compound.

12. A method for reducing fouling in a hydrocarbon refining process comprising

providing a crude hydrocarbon for a refining process;

adding an additive to the crude hydrocarbon, the additive represented by the formula for the compound according to any one of claims 1-11.

13. A system for refining hydrocarbons comprising:

at least one crude hydrocarbon refinery component; and

crude hydrocarbon in fluid communication with the at least one crude hydrocarbon refinery component, the crude hydrocarbon comprising an additive represented by the formula for the compound according to any one of claims 1-11.

14. The system of claim 13, wherein the at least one crude hydrocarbon refinery component is selected from a heat exchanger, a furnace, a crude preheater, a coker preheater, a FCC slurry bottom, a debutanizer exchanger, a debutanizer tower, a feed/effluent exchanger, a furnace air preheater, a flare compressor component, a steam cracker, a steam reformer, a distillation column, a fractionation column, a scrubber, a reactor, a liquid-jacketed tank, a pipestill, a coker, and a visbreaker.

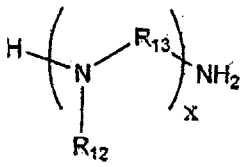
15. A method for preparing an antifoulant useful for reducing fouling in a hydrocarbon refining process, the method comprising:

(a) reacting a polymer base unit R_{11}, which is a branched or straight-chained C_{10}-C_{800} polypropylene or poly(ethylene-co-propylene) having a vinyl terminal group, with an acrylic compound represented by $H_2C=CH-C(O)-Y$, wherein Y is a functional group selected from halogen, -R*, -OR*, -SR*, -NR*R**, wherein R* and R** are both independently selected from hydrogen and substituted or unsubstituted C_1-C_{10} alkyl or C_1-C_{10} alkenyl, and wherein a

hydrogen connecting to either of the carbons forming the double bond may be optionally replaced by a C_1-C_4 alkyl; wherein the reaction between R_{11} and the acrylic compound is a cross-metathesis reaction;

(b) optionally, hydrogenating the compound formed in (a);

(c) reacting the compound formed in (a) or (b) with a polyamine represented by



wherein R_{13} is hydrogen or a C_1-C_{10} branched or straight chained alkyl optionally substituted with one or more amine groups, R_{12} is a C_1-C_{10} branched or straight chained alkylene group, and x is an integer between 1 and 10, wherein the -N(R_{12})-R_{13}- unit is optionally interrupted in one or more places by a heterocyclic or homocyclic cycloalkyl group, and wherein when the -(R_{12})-R_{13}- unit along with the terminal nitrogen atom forms a heterocyclic cycloalkyl group at the right terminal end, the terminal $-NH_2$ is replaced by a -NH- group as required by valency.

16. The method of claim 15, wherein R_{11} comprises polypropylene.

17. The method of claim 16, wherein the polypropylene is atactic polypropylene, isotactic polypropylene, or syndiotactic polypropylene.

18. The method of claim 16, wherein the polypropylene is amorphous.

19. The method of claim 16, wherein the polypropylene include isotactic or syndiotactic crystallizable units.

20. The method of claim 16, wherein the polypropylene include meso diads constituting from about 30% to about 99.5% of the total diads of the polypropylene.

21. The method of claim 15, wherein the molar ratio of R_{11}: polyamine ranges from about 5:1 to about 1:1.

22. The method of claim 16, wherein R_{11} has a number-averaged molecular weight of from 300 to 30000 g/mol.

23. The method of claim 22, wherein R_{11} has a number-averaged molecular weight of from 500 to 5000 g/mol.

24. The method of claim 15, wherein R_{11} comprises from 10 mole % to 50 mole % of ethylene units and from 90 mole % to 50 mole % propylene units.

25. The method of claim 24, wherein R_{11} comprises from 20 mole % to 50 mole % of ethylene units.

26. The method of claim 15, wherein at least 50 % of the terminal vinyl groups of R_{11} are an allylic vinyl group.

27. The method of claim 15, wherein the polyamine is selected from ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, and hexaethyleneheptamine.

28. The method of claim 15, wherein the acrylic compound is acrylic acid or methacrylic acid.

29. The method of claim 15, wherein the acrylic compound is a (C_1-C_4) alkyl acrylate or a (C_1-C_4)alkyl methacrylate.

30. The method of claim 29, wherein the acrylic compound is selected from methyl acrylate, methyl methacrylate, ethyl acrylate, and ethyl methacrylate.

31. A compound useful for reducing fouling in a hydrocarbon refining process produced by the method according to anyone of claims 15-30.

32. A method for reducing fouling in a hydrocarbon refining process comprising

providing a crude hydrocarbon for a refining process;

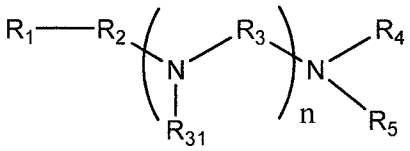
adding an additive to the crude hydrocarbon, the additive being an antifoulant produced by the method according to any one of claims 5-30.

CLAIMS

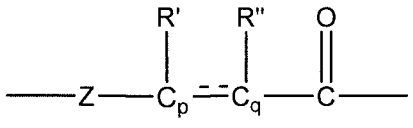
1. A method for reducing fouling in a hydrocarbon refining process comprising

providing a crude hydrocarbon for a refining process;

adding an additive to the crude hydrocarbon, the additive represented by the formula:



wherein R_1 is a branched or straight-chained C_{64}-C_{342} alkyl or alkenyl group;

R_2 is , wherein the carbonyl carbon connects to nitrogen, the bond between carbons C_p and C_q is either a single or double bond, wherein when the bond between carbons C_p and C_q is a single bond, a hydrogen is attached to each of C_p and C_q as required by valency; R' and R" are independently H or unsubstituted or substituted C_1-C_4 alkyl or C_1-C_4 alkenyl, and Z is a bond or unsubstituted or substituted C_1-C_4 alkylene;

R_3 is a C_1-C_{10} branched or straight chained alkylene group;

n is an integer from 1 to 10;

R_4 and R_5 are both independently selected from hydrogen and -R_6-R_7, wherein R_6 is defined the same as R_2 above, and R_7 is a C_{64}-C_{342} branched or straight chained alkyl or alkenyl group, or one of R_4 and R_5 is absent as required by valency and the other of R_4 and R_5 is hydrogen or -R_6-R_7 as defined above;

R_{31} is hydrogen or -R_8-R_9, wherein R_8 is defined the same as R_2 above, and R_9 is branched or straight-chained C_{64}-C_{342} alkyl or alkenyl group, or R_8 and R_9 together are a C_1-C_{10} branched or straight chained alkyl group optionally substituted with one or more amine groups;

and wherein the $-N(R_{31})-R_3-$ repeat unit is optionally interrupted in one or more places by a heterocyclic or homocyclic cycloalkyl group.

2. The method of claim 1, wherein at least one of R_1, R_7, and R_9 comprises polypropylene.

3. The method of claim 2, wherein the polypropylene is atactic polypropylene, isotactic polypropylene, or syndiotactic polypropylene.

4. The method of claim 2, wherein the polypropylene is amorphous.

5. The method of claim 2, wherein the polypropylene include isotactic or syndiotactic crystallizable units.

6. The method of claim 2, wherein the polypropylene include meso diads constituting from about 30% to about 99.5% of the total diads of the polypropylene.

7. The method of claim 2, wherein at least one of R_1, R_7, and R_9 has a number-averaged molecular weight of from about 300 to about 30000 g/mol.

8. The method of claim 2, wherein at least one of R_1, R_7, and R_9 has a number-averaged molecular weight of from about 500 to about 5000 g/mol.

9. The method of claim 1, wherein at least one of R_1, R_7, and R_9 comprises polyethylene.

10. The method of claim 1, wherein at least one of R_1, R_7, and R_9 comprises poly(ethylene-co-propylene).

11. The method of claim 10, wherein at least one of R_1, R_7, and R_9 comprises from about 1 mole % to about 90 mole % of ethylene units and from about 99 mole % to about 10 mole% propylene units.

12. The method of claim 11, wherein at least one of R_1, R_7, and R_9 comprises from about 10 mole % to about 50 mole % of ethylene units.

13. The method of claim 1, wherein R_1 is poly(ethylene-co-propylene), R_3 is $-CH_2CH_2-$, R_{31} is hydrogen, and R_4 and R_5 are both hydrogen.

14. The method of claim 1, wherein R_2 is $-CH_2-CH_2-C(O)-$.

15. The method of claim 1, wherein the nitrogen content in the additive is about 1 wt% to about 10 wt% based on the total weight of the additive.

16. A method for reducing fouling in a hydrocarbon refining process comprising

providing a crude hydrocarbon for a refining process;

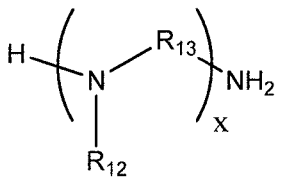
adding an additive to the crude hydrocarbon, the additive being a reaction product of

(a) a polymer base unit R_{11}, which is a branched or straight-chained C_{64}-C_{342} alkyl or alkenyl group having a vinyl terminal group;

(b) an acrylic compound represented by $H_2C=CH-C(O)-Y$, wherein Y is a functional group selected from halogen, -R*, -OR*, -SR*, -NR*R**, where R* and R** are both independently selected from hydrogen and substituted or unsubstituted C_1-C_{10} alkyl or C_1-C_{10} alkenyl, and wherein a hydrogen connecting to either of the carbons forming the double bond may be optionally replaced by a C_1-C_4 alkyl;

(c) optionally, hydrogen;

(d) a polyamine represented by the formula:



wherein R_{12} is hydrogen or a C_1-C_{10} branched or straight chained alkyl optionally substituted with one or more amine groups, R_{13} is a C_1-C_{10} branched or straight chained alkylene group, and x is an integer between 1 and 10, wherein the

-$N(R_{12})$-R_{13}- unit is optionally interrupted in one or more places by a heterocyclic or homocyclic cycloalkyl group, and wherein when the -$N(R_{12})$-R_{13}- unit along with the terminal nitrogen atom forms a heterocyclic cycloalkyl group at the right terminal end, the terminal $-NH_2$ is replaced by a -NH- group as required by valency.

17. The method of claim 16, wherein the polyamine is selected from ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, and hexaethyleneheptamine.

18. The method of claim 16, wherein the polyamine is a heavy polyamine.

19. The method of claim 16, wherein R_{11} comprises polypropylene.

20. The method of claim 16, wherein the molar ratio of R_{11} : polyamine ranges from about 5:1 to about 1:1.

21. The method of claim 19, wherein R_{11} has a number-averaged molecular weight of from about 300 to about 30000 g/mol.

22. The method of claim 21, wherein R_{11} has a number-averaged molecular weight of from about 500 to about 5000 g/mol.

23. The method of claim 19, wherein the polypropylene is atactic polypropylene, isotactic polypropylene, or syndiotactic polypropylene.

24. The method of claim 19, wherein the polypropylene is amorphous.

25. The method of claim 19, wherein the polypropylene include isotactic or syndiotactic crystallizable units.

26. The method of claim 19, wherein the polypropylene include meso diads constituting from about 30% to about 99.5% of the total diads of the polypropylene.

27. The method of claim 16, wherein R_{11} comprises polyethylene.

28. The method of claim 16, wherein R_{11} comprises poly(ethylene-co-propylene).

29. The method of claim 28, wherein R_{11} comprises from about 10 mole % to about 90 mole % of ethylene units and from about 90 mole % to about 10 mole % propylene units.

30. The method of claim 29, wherein R_{11} comprises from about 20 mole % to about 50 mole % of ethylene units.

31. The method of claim 29, wherein the acrylic compound is acrylic acid or methacrylic acid.

32. The method of claim 16, wherein the acrylic compound in (a) is a (C_1-C_4)alkyl acrylate or a (C_1-C_4)alkyl methacrylate.

33. The method of claim 32, wherein the acrylic compound in (a) is selected from methyl acrylate, methyl methacrylate, ethyl acrylate, and ethyl methacrylate.

34. The method of claim 16, wherein at least 50 % of the terminal vinyl groups of R_{11} are an allylic vinyl group.