CLAIMS

1. A framing associative polymer comprising:

a linear, branched, or hyperbranched polymer backbone having at least two ends and a functional group presented at two or more ends of the at least two ends of the linear, branched, or hyperbranched polymer backbone;

wherein the linear, branched, or hyperbranched polymer backbone is substantially soluble in a host non-polar composition,

wherein a number of the functional groups presented at the two or more ends is formed by associative functional groups each capable of undergoing an associative interaction with another associative functional group in the non-polar composition with an association constant (k), wherein

$$k\ (M^{-1}) \geq \frac{\frac{4}{3}\pi\left(R_g{}^2\right)^{\frac{3}{2}} N_a}{n_F} \times 10^{-23}$$

in which R_g is the radius of gyration of the framing associative polymer in the non-polar composition in nanometers, N_a is Avogadro's constant; and n_F is the average number of the associative functional groups in the framing associative polymer,

wherein a longest span of the framing associative polymer has a contour length L_f, such that $\frac{1}{2} L_{bf} \leq L_f < L_{bf}$,

wherein L_{bf} is a rupture length of the framing associative polymer in nanometers when the framing associative polymer is comprised within the host non-polar composition at framing associative polymer concentration c to provide an associative non-polar composition in a flow, L_{bf} being given by implicit function

$$F_{bf} = \frac{\pi\mu^2\ \mathrm{Re}^{3/2}\left(L_{bf}\right)^2}{4\rho d^2 \ln\left(L_{bf}\right)} \times 10^{-9}$$

in which F_{bf} is the rupture force of the framing associative polymer in nanonewtons, *Re* is the Reynolds number, *d* is the characteristic length of the flow in meters, μ is

the viscosity of the host non-polar composition μ_h or the viscosity of the associative non polar composition μ_a in Pa·s, and ρ is the density of the host non-polar composition ρ_h or the viscosity of the associative non polar composition ρ_a in kg/m^3,

wherein when c $\leq$2c*, μ is the viscosity of the host non-polar composition μ_h, ρ is the density of the host non-polar composition ρ_h, and when c > 2c*, μ is the viscosity of the associative non-polar composition μ_a, and ρ is the density of the associative non-polar composition ρ_a,

and wherein

$$c^* = \frac{3M_w}{4\pi(R_g^2)^{3/2} N_a},$$

in which M_w is the weight-average molecular weight, R_g is the radius of gyration, and N_a is Avogadro's constant.

2. The framing associative polymer of claim 1, having a weight-average molecular weight equal to or lower than about 2,000,000 g/mol.

3. The framing associative polymer of claim 1, having a weight-average molecular weight 400,000<M_w [g/mol]$\leq$,000,000.

4. The framing associative polymer of claim 1, wherein the association constant is 6 $\leq \log_{10} k \leq$14.

5. The framing associative polymer of claim 1, wherein the association constant is 6.9 $\leq \log_{10} k \leq$ 7.8.

6. The framing associative polymer of claim 1, wherein the associative functional group is a carboxylic acid and the another associative functional group is a carboxylic acid, or the associative functional group is a carboxylic acid and the another associative functional group is an amine, or the associative functional group is an alcohol and the another associative functional group is an amine, or the associative functional group is

an alcohol and the another associative functional group is a carboxylic acid, or the associative functional group is a diacetamidopyridine and the another associative functional group is a thymine, or the associative functional group is a Hamilton Receptor and the another associative functional group is a cyanuric acid, the associative functional group is zinc sulfonate or palladated sulfur–carbon–sulfur (SCS) pincer and the another associative functional group is selected from pyridine or primary, secondary and tertiary amines.

7. The framing associative polymer of claim 1, wherein the another associative functional group is presented at least one end of a different associative polymer.

8. The framing associative polymer of claim 1, wherein the framing associative polymers are formed by at least two structure units having formula [[FG-chain]-[node]$_z$-]- **(I)** and optionally one or more structural units having formula -[[node]- [chain]]- **(II),**

wherein:

FG is an associative functional group (FGa);

chain is a non-polar polymer substantially soluble in a non-polar composition, the polymer having formula:

$$R_1\text{-}[A]_n R_2 \textbf{ (III)}$$

wherein:

A is a chemical and in particular an organic moiety forming the monomer of the polymer;

R_1 and R_2 are independently selected from any carbon based or organic group with one of R_1 and R_2 linked to an FG or a node and the other one of R_1 and R_2 linked to an FG or a node; and

n is an integer ≥ 1;

z is 0 or 1;

node is a covalently linked moiety linking one of R_1 and R_2 of at least one first chain with one of the R_1 and R_2 of at least one second chain;

wherein the FG, chain and node of different structural units of the polymer can be the same or different;

and wherein in at least one structure unit having formula [[FG-chain]-[node]$_z$-] **(I)** and optionally in one or more structural units having formula -[[node]- [chain]]- **(II)**, n is ≥250.

9. The framing associative polymer of claim 8, wherein the associative functional group FGa is selected from diacetamidopyridine group, thymine group, Hamilton Receptor group, cyanuric acid group, carboxylic acid group, primary secondary or tertiary amine group, primary secondary and tertiary alcohol group, zinc sulfonate, palladated sulfur–carbon–sulfur (SCS) pincer pyridine or primary, secondary and tertiary amines.

10. The framing associative polymer of claim 8, wherein A is a diene, olefin, styrene, acrylonitrile, methacrylate or acrylate, vinyl acetate, dichlorodimethylsilane, tetrafluoroethylene, acids, esters, amides, amines, glycidyl ethers, or isocyanates, siloxane.

11. The framing associative polymer of claim 8, wherein n is equal to or greater than 200 or equal to or greater than 800.

12. An associative non-polar composition comprising:

a host composition having a viscosity μ_h, a density ρ_h, a dielectric constant equal to or less than about 5, and

at least one framing associative polymer of claim 1, soluble in the host composition and having a longest span with a contour length ½ $L_{bf} \leq L_f < L_{bf}$,

wherein the at least one framing associative polymer is comprised in the host composition in a concentration c between from about 0.01 c^* to about 10c^* wherein

$$c^* = \frac{3M_w}{4\pi(R_g^2)^{3/2} N_a},$$

in which M_w is the weight-average molecular weight, R_g is the radius of gyration, and

N_a is Avogadro's constant,

wherein L_{bf} is a rupture length of the at least one framing associative polymer in nanometers when the at least one framing associative polymer is within the host non-polar composition at a concentration c to provide the associative non-polar composition in a flow, L_{bf} being given by implicit function

$$F_{bf} = \frac{\pi\mu^2 \,\mathrm{Re}^{3/2}\left(L_{bf}\right)^2}{4\rho d^2 \ln\left(L_{bf}\right)} \times 10^{-9}$$

in which F_{bf} is the rupture force of the at least one framing associative polymer in nanonewtons, *Re* is the Reynolds number, *d* is the characteristic length of the flow in meters, μ is the viscosity of the host non-polar composition μ_h or the viscosity of the associative non polar composition μ_a in Pa·s, and ρ is the density of the host non-polar composition ρ_h or the viscosity of the associative non polar composition ρ_a in kg/m^3,

wherein, when $c \leq 2c^*$, μ is μ_h, and ρ is ρ_h, and when $c > 2c^*$, μ is the viscosity of the associative non-polar composition μ_a, and ρ is the density of the associative non-polar composition ρ_a,

and wherein the concentration is suitable to control at least one rheological property of the host composition.

13. The non-polar composition of claim 12, wherein when the at least one rheological property is selected from drag reduction, mist control, lubrication and/or viscoelastic properties.

14. The non-polar composition of claim 12, wherein when the concentration of the at least one framing associative polymer is between 0.05 c* and 0.1c*.

15. The non-polar composition of claim 12, wherein when the concentration of the at least one framing associative polymer is between 0.1 c* and c*.

16. The non-polar composition of claim 12, wherein the concentration of the at least one framing associative polymer is between 2*c** to 10*c**.

17. The non-polar composition of claim 12, wherein the at least one framing associative polymer comprises one or more pairs of telechelic polymers.

18. The non-polar composition of claim 17, wherein the one or more pairs of telechelic polymers comprise complementary associative functional groups, wherein the complementary associative functional groups comprise one or more of carboxylic acids with other carboxylic acids, carboxylic acids with amines, alcohols with amines, alcohols with carboxylic acids, diacetamidopyridine with thymine, the Hamilton Receptor with cyanuric acid, zinc sulfonate or palladated sulfur–carbon–sulfur (SCS) pincer with pyridine or primary, secondary or tertiary amines.

19. The non-polar composition of claim 12, further comprising a capping associative polymer at a concentration up to 20wt% of a total associative polymer concentration in the non-polar composition, wherein the capping associative polymer comprises:

a linear, branched, or hyperbranched polymer backbone having at least two ends and one associative functional groups presented at one end of the at least two ends of the backbone.

wherein the linear or branched backbone is substantially soluble in the host composition, and the associative functional group is capable of undergoing an associative interaction with another associative functional group in the non-polar composition with an association constant (k) wherein

$$\mathrm{k}\ (\mathrm{M}^{-1}) \geq \frac{4}{3}\pi\left(R_g{}^2\right)^{\frac{3}{2}} N_a \times 10^{-23}$$

in which Rg is the radius of gyration of the associative polymer in the non-polar composition in nanometer, and N_a is Avogadro's constant.

20. The non-polar composition of claim 12, wherein the host composition is a hydrocarbon composition, a fluorocarbon composition or a silicone composition.

21. The non-polar composition of claim 12, wherein the host composition is a mineral oil, a biofuel, pentane, hexane, cyclohexane, benzene, toluene, chloroform and diethyl ether, liquefied petroleum gas, liquid methane, butane, gasoline, kerosene, jet fuel and

diesel fuel.

22. The non-polar composition of claim 12, wherein the host composition comprises crude oil or a refined fuel.

23. The non-polar composition of claim 12, wherein the host composition comprises a refined fuel selected from Jet-A, Jet-A1, kerosene, JP-8, gasoline and/or diesel.

24. A method to control resistance to flow and/or flow rate enhancement of an associative non-polar composition alone or in combination with another physical and/or chemical property of the associative non-polar composition in a flow characterized by a Reynolds number Re, and a characteristic length *d*, the method comprising

providing a host composition having a viscosity μ_h, a density ρ_h and a dielectric constant equal to or less than about 5;

providing at least one framing associative polymer of claim 1 substantially soluble in the host composition and having a longest span with a contour length $\frac{1}{2} L_{bf} \leq L_f < L_{bf}$, the at least one framing associative polymer having a weight-average molecular weight equal to or higher to 200,000 g/mol; and

combining the host composition and the at least one framing associative polymer at a concentration c selected between from about 0.01 c* to 1c*, depending on the weight-average molecular weight and/or Radius of gyration of the at least one framing associative polymer and on a physical and/or chemical property to be controlled,

wherein

$$c^* = \frac{3M_w}{4\pi(R_g^2)^{3/2} N_a},$$

in which M_w is the weight-average molecular weight, R_g is the radius of gyration, and N_a is Avogadro's constant,

wherein L_{bf} is a rupture length of the at least one framing associative polymer in nanometers when the at least one framing associative polymer is within the host non-

polar composition at a concentration c to provide the associative non-polar composition in a flow, L_{bf} being given by implicit function

$$F_{bf} = \frac{\pi \mu_h^{\,2} \, \mathrm{Re}^{3/2} \left(L_{bf}\right)^2}{4 \rho_h d^2 \ln\left(L_{bf}\right)} \times 10^{-9}$$

in which F_{bf} is the rupture force of the framing associative polymer in nanonewtons, *Re* is the Reynolds number of the flow, *d* is the characteristic length of the flow in meters, μ_h is the viscosity of the host non-polar composition in Pa·s, and ρ_h is the density of the host non-polar composition in kg/m^3.

25. The method of claim 24, wherein the association constant of the at least one framing associative polymer is between $7 \leq \log_{10} k \leq 14$.

26. The method of claim 24, wherein the at least one framing associative polymer has a weight-average molecular weight $400{,}000 < M_w$ [g/mol] $\leq 1{,}000{,}000$.

27. The method of claim 24, wherein the concentration c is about 0.1 c* to 0.5*c**.

28. The method of claim 24, wherein the concentration c about 0.5*c** to 1*c** and the another physical and/or chemical property is sizes, and/or distribution of sizes of the droplets of a fluid.

29. The method of claim 24, wherein the concentration c is below or approximately equal *c** and the another physical and/or chemical property is enhanced lubrication.

30. A method to control sizes, and/or distribution of sizes, of the droplets of fluid, alone or in combination with another physical and/or chemical property, in an associative non-polar composition in a flow characterized by a Reynolds number Re, and a characteristic length *d*,

the method comprising

providing a host composition having a viscosity μ_h, a density ρ_h and a dielectric constant equal to or less than about 5;

providing at least one framing associative polymer of claim 1 substantially soluble

in the host composition and having a longest span with a contour length ½ L_{bf} ≤L_f < L_{bf}, the at least one framing associative polymer having a weight-average molecular weight equal to or higher to 60,000 g/mol; and

combining the host composition and the at least one framing associative polymer at a concentration c selected between from about 0.05c^* to about 3c^*, depending on the weight-average molecular weight and/or Radius of gyration of the at least one framing associative polymer and on a physical and/or chemical property to be controlled,

wherein

$$c^* = \frac{3M_w}{4\pi(R_g^2)^{3/2} N_a},$$

in which M_w is the weight-average molecular weight, R_g is the radius of gyration, and N_a is Avogadro's constant,

wherein L_{bf} is a rupture length of the framing associative polymer in nanometers when the at least one framing associative polymer is within the host non-polar composition at a concentration c to provide the associative non-polar composition in a flow, L_{bf} being given by implicit function

$$F_{bf} = \frac{\pi\mu^2 \mathrm{Re}^{3/2}(L_{bf})^2}{4\rho d^2 \ln(L_{bf})} \times 10^{-9}$$

in which F_{bf} is the rupture force of the at least one_framing associative polymer in nanonewtons, Re is the Reynolds number, d is the characteristic length of the flow in meters, μ is the viscosity of the host non-polar composition μ_h or the viscosity of the associative non polar composition μ_a in Pa·s, and ρ is the density of the host non-polar composition ρ_h or the viscosity of the associative non polar composition ρ_a in kg/m^3,

wherein, when c ≤2c*, μ is μ_h, and ρ is ρ_h, and when c > 2c*, μ is the viscosity of the associative non-polar composition μ_a, and ρ is the density of the associative non-polar composition ρ_a.

31. The method of claim 30, wherein the association constant of the at least one framing associative polymer is between $7 \leq \log_{10} k \leq 14$.

32. The method of claim 30, wherein the at least one framing associative polymer has a weight-average molecular weight between 400,000 g/mol to 1,000,000 g/mol.

33. The method of claim 30, wherein the concentration of the at least one framing associative polymer is between 0.5 c* and c*.

34. The method of claim 30, wherein the concentration c is about 0.5 c* or between about $0.5c^*$ to $1c^*$ and the another physical and/or chemical property is drag reduction.

35. The method of claim 30, wherein the concentration c is below or approximately equal c^* and the another physical and/or chemical property is enhanced lubrication.

36. A system for controlling a physical and/or chemical property of an associative non-polar composition in a flow characterized by a Reynolds number Re, and a characteristic length *d*, the system comprising at least two between at least one framing associative polymer of claim 1 and at least one host composition having a viscosity μ_h, a density ρ_h and a dielectric constant equal to or less than 5,

wherein the at least one framing associative polymer is substantially soluble in the host composition,

wherein the longest span of the at least one_framing associative polymer has a contour length $½\ L_b \leq L_f < L_b$, wherein L_b is a rupture length of the at least one_framing associative polymer in nanometers when the framing associative polymer is within the host non-polar composition in a flow to provide an associative non-polar composition wherein the at least one framing associative polymer is comprised at a concentration c, and L_b is given by the implicit function

$$F_{bf} = \frac{\pi\mu^2 \,\mathrm{Re}^{3/2}\left(L_{bf}\right)^2}{4\rho d^2 \ln\left(L_{bf}\right)} \times 10^{-9}$$

in which F_{bf} is the rupture force of the at least one framing associative polymer in nanonewtons, *Re* is the Reynolds number, *d* is the characteristic length of the flow in

meters, μ is the viscosity of the host non-polar composition μ_h or the viscosity of the associative non polar composition μ_a in Pa·s, and ρ is the density of the host non-polar composition ρ_h or the viscosity of the associative non polar composition ρ_a in kg/m^3,

and wherein, when $c \leq 2c^*$, μ is μ_h, and ρ is ρ_h, and when $c > 2c^*$, μ is the viscosity of the associative non-polar composition μ_a, and ρ is the density of the associative non-polar composition ρ_a.