each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

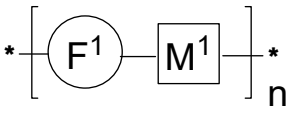
each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–.

In another aspect of the present disclosure, there is provided a polymeric tandem dye comprising:

a water soluble light harvesting multichromophore comprising a conjugated segment having the structure of formula (I):



(I)

wherein:

F^1 is a fused tricyclic co-monomer substituted with a water soluble group (WSG);

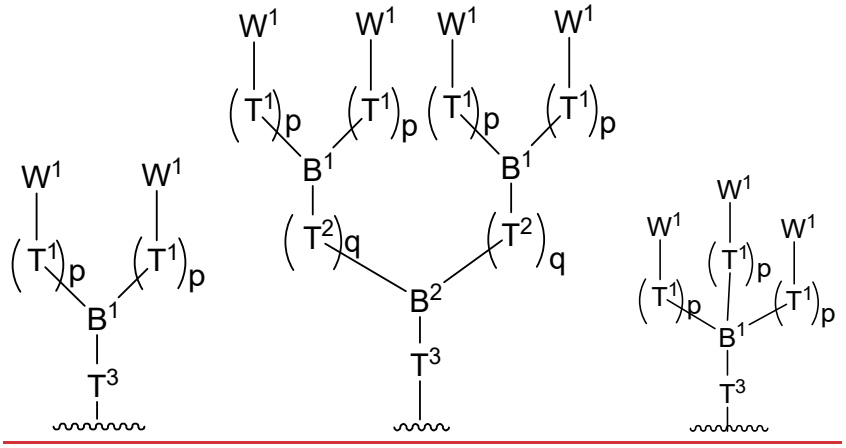
M^1 is an aryl or heteroaryl co-monomer;

n is an integer from 1 to 100,000; and

* denotes a site for covalent attachment to the unsaturated backbone of a conjugated polymer or an end group;

wherein at least one of F^1 and M^1 is substituted with a branched non-ionic water soluble group (WSG) comprising two or more water soluble polymers each having 6-50 monomeric units;

wherein the branched non-ionic water soluble group is capable of imparting solubility in water in excess of 50 mg/mL to the multichromophore and has one of the following formulae:



wherein:

each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

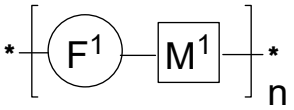
T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–; and

a signaling chromophore covalently linked to the multichromophore in energy-receiving proximity therewith.

In a further aspect of the present disclosure, there is provided an aggregation-resistant labelled specific binding member comprising:

a water soluble light harvesting multichromophore comprising a conjugated segment having the structure of formula (I):



(I)

wherein:

F^1 is a fused tricyclic co-monomer substituted with a water soluble group (WSG);

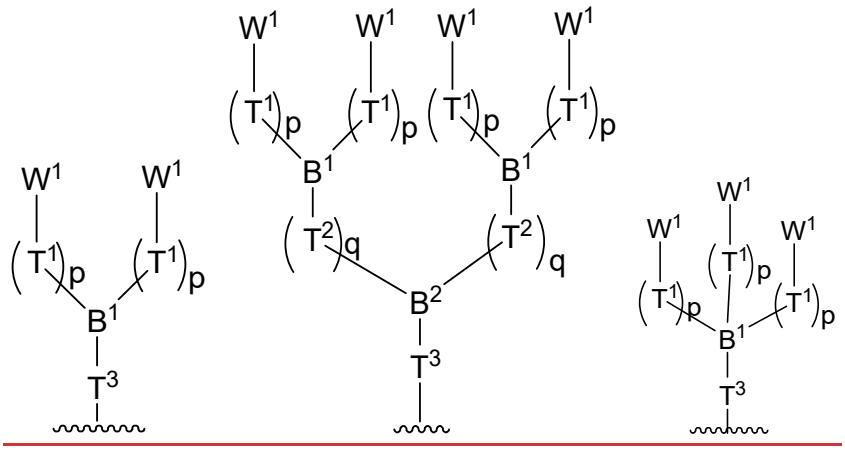
M^1 is an aryl or heteroaryl co-monomer;

n is an integer from 1 to 100,000; and

* denotes a site for covalent attachment to the unsaturated backbone of a conjugated polymer or an end group;

wherein at least one of F^1 and M^1 is substituted with a branched non-ionic water soluble group (WSG) comprising two or more water soluble polymers each having 6-50 monomeric units;

wherein the branched non-ionic water soluble group is capable of imparting solubility in water in excess of 50 mg/mL to the multichromophore and has one of the following formulae:



wherein:

each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–; and

a specific binding member covalently linked to the multichromophore.

BRIEF DESCRIPTION OF THE FIGURES

It is understood that the drawings, described below, are for illustration purposes only. The drawings are not intended to limit the scope of the present teachings in any way.

FIG. 1 depicts several exemplary co-monomers of the present disclosure that include exemplary branched non-ionic water soluble groups (WSG).

FIG. 2 depicts the structural formula of exemplary tandem polymeric dyes of the present disclosure that include fluorene co-monomers having exemplary branched non-ionic water soluble groups (WSG).

FIG. 3 depicts the structural formula of exemplary tandem polymeric dyes of the present disclosure that include aryl co-monomers having exemplary branched non-ionic water soluble groups (WSG), where x, y and z represent mol % values of the co-monomers in the polymeric dye.

DEFINITIONS

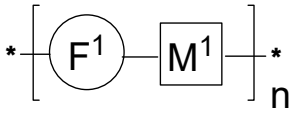
Before describing exemplary embodiments in greater detail, the following definitions are set forth to illustrate and define the meaning and scope of the terms used in the description.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Still, certain terms are defined below for the sake of clarity and ease of reference.

It must be noted that as used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise. For example, the term “a primer” refers to one or more primers, i.e., a single primer and multiple primers. It is further noted that the claims can be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis

What is claimed is:

1. A water soluble light harvesting multichromophore comprising a conjugated segment having the structure of formula (I):



(I)

wherein:

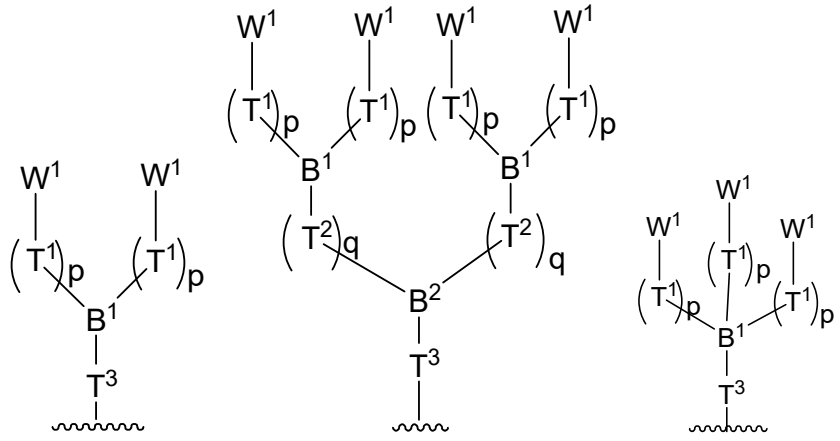
F^1 is a fused tricyclic co-monomer substituted with a water soluble group (WSG);

M^1 is an aryl or heteroaryl co-monomer;

n is an integer from 1 to 100,000; and

* denotes a site for covalent attachment to the unsaturated backbone of a conjugated polymer or an end group;

wherein at least one of F^1 and M^1 is substituted with a branched non-ionic water soluble group comprising two or more water soluble polymers each having 6-50 monomeric units; wherein the branched non-ionic water soluble group is capable of imparting solubility in water in excess of 50 mg/mL to the multichromophore and has one of the following formulae:



wherein:

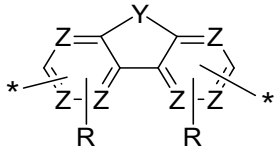
each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–.

2. The water soluble light harvesting multichromophore according to claim 1, wherein the fused tricyclic co-monomer is described by the following structure:



where:

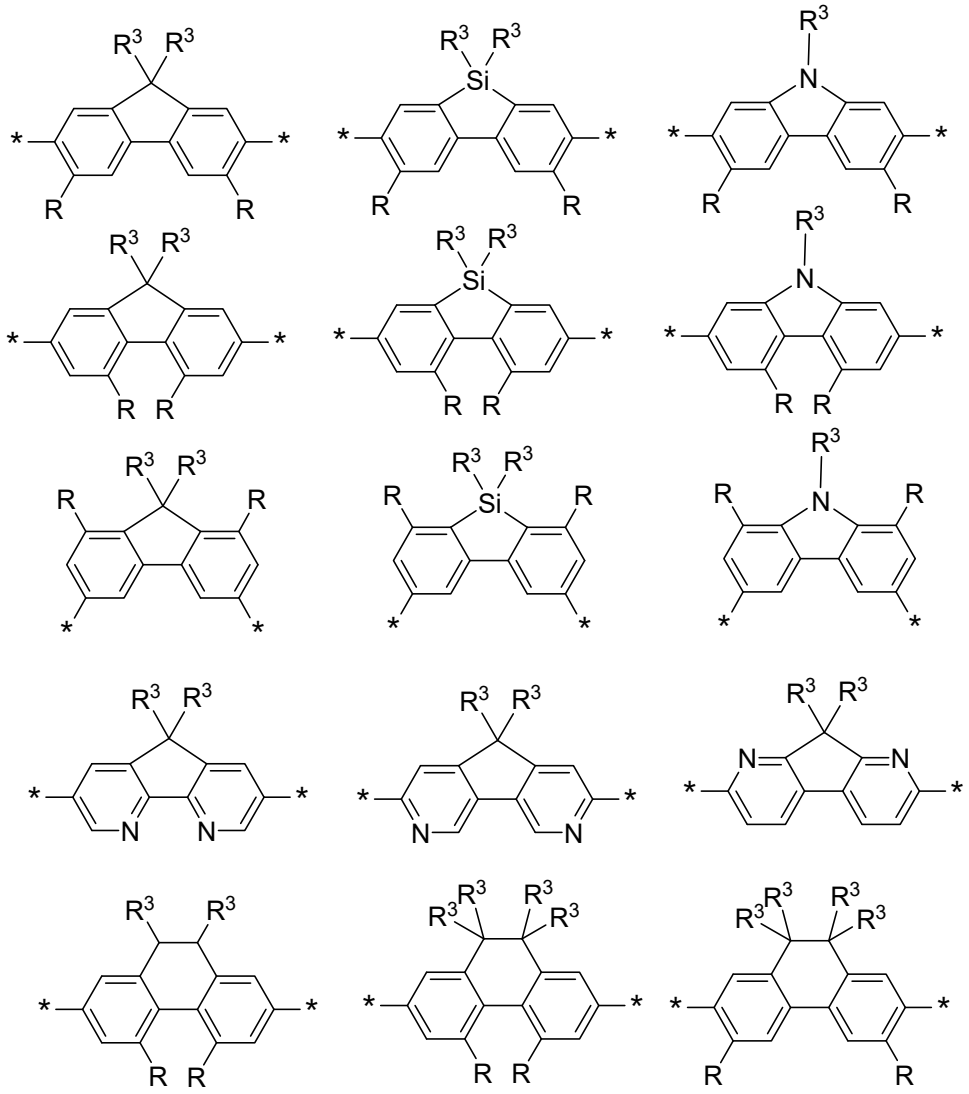
Y is $C(R^3)_2$, $-C(R^3)_2C(R^3)_2-$, $-C(R^3)_2Si(R^3)_2-$, NR^3, $Si(R^3)_2$ or Se;

each Z is independently CH, CR or N, wherein at least two of Z in each ring is CH or CR;

each R^3 is independently selected from H, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, alkoxy, substituted alkoxy, amido, substituted amido, an aralkyl, a substituted aralkyl, a PEG moiety, $-L^1-Z^1$, where L^1 is a linker and Z^1 is a chemoselective tag and a WSG; and

each R is independently selected from H, WSG, halogen, alkoxy, substituted alkoxy, alkyl and substituted alkyl or wherein two R groups are optionally cyclically linked to provide a carbocyclic or heterocyclic ring.

3. The water soluble light harvesting multichromophore according to claim 2, wherein the fused tricyclic co-monomer is described by one of the following structures:

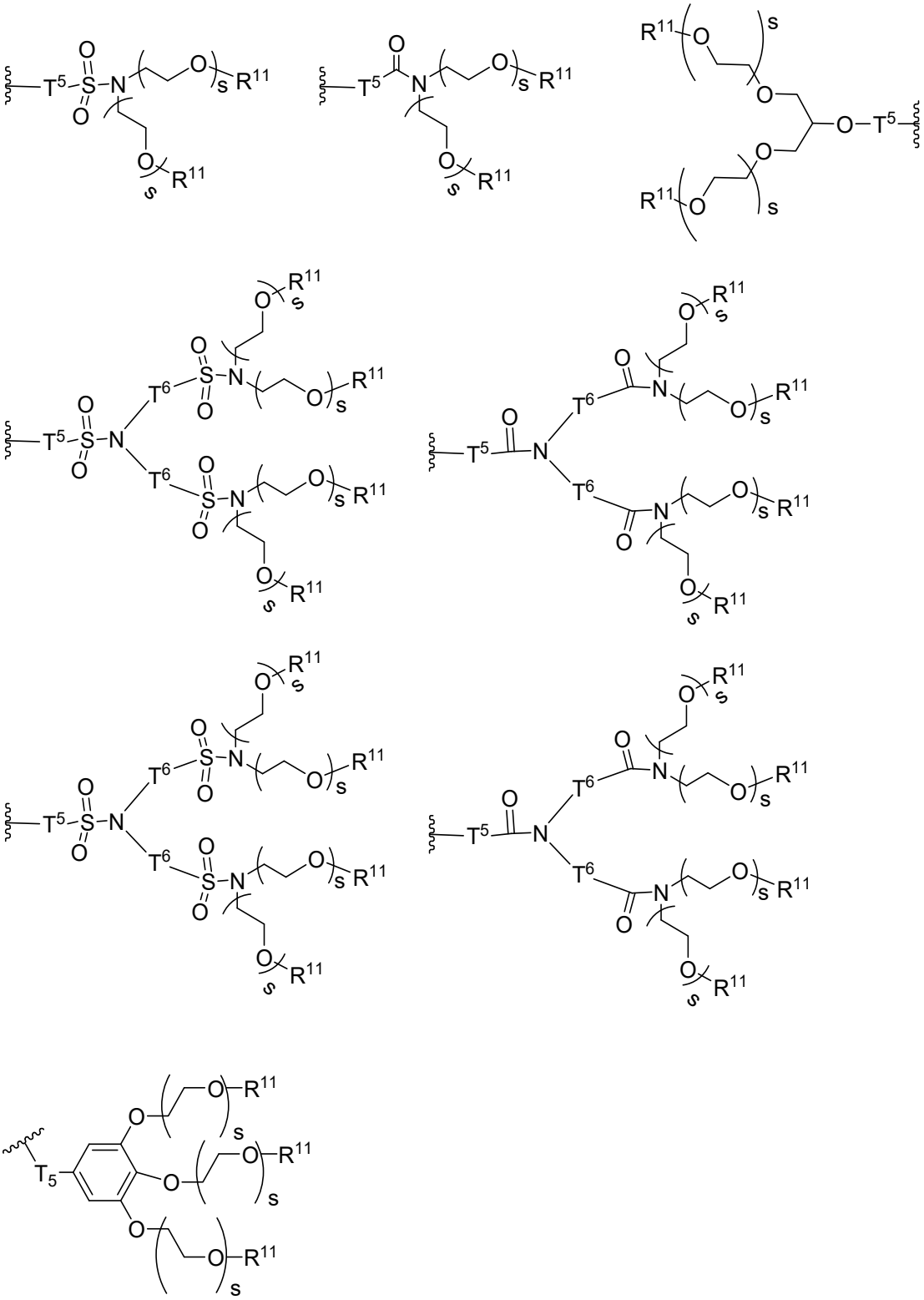


wherein:

each R^3 is independently selected from H, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, alkoxy, substituted alkoxy, amido, substituted amido, an aralkyl, a substituted aralkyl, a PEG moiety, $-L^1-Z^1$, where L^1 is a linker and Z^1 is a chemoselective tag and a WSG; and

each R is independently selected from H, WSG, halogen, alkoxy, substituted alkoxy, alkyl and substituted alkyl or wherein two R groups are optionally cyclically linked to provide a carbocyclic or heterocyclic ring.

4. The water soluble light harvesting multichromophore according to claim 1, wherein the branched non-ionic WSG is selected from one of the following structures:



wherein:

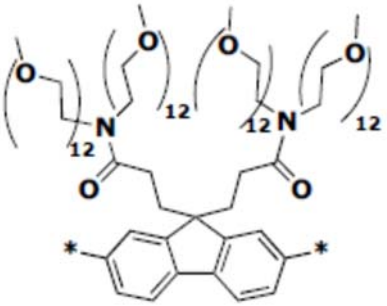
T^5 is an optional linker to the fused 6-5-6 tricyclic co-monomer;

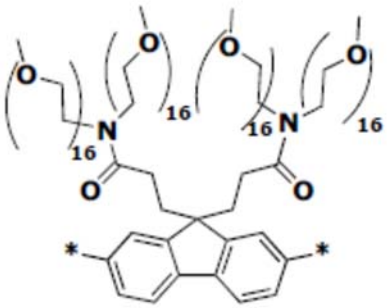
T^6 is a linker;

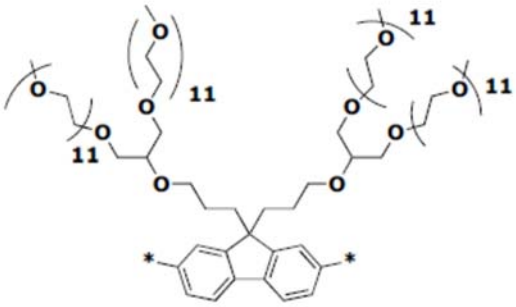
each s is an integer from 6 to 24; and

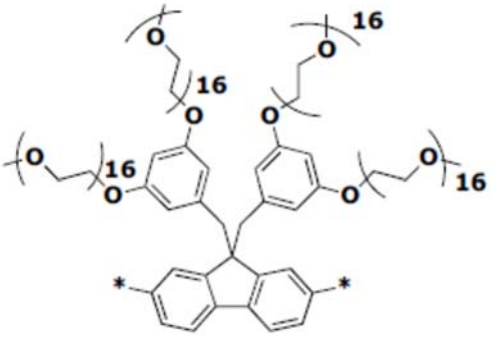
each R^{11} is independently hydrogen, an alkyl or a substituted alkyl.

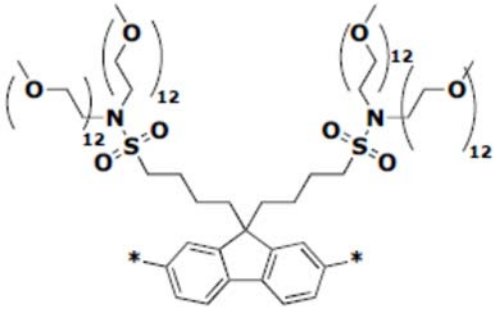
5. The water soluble light harvesting multichromophore according to claim 1, wherein F^1 is selected from one of the following co-monomers:

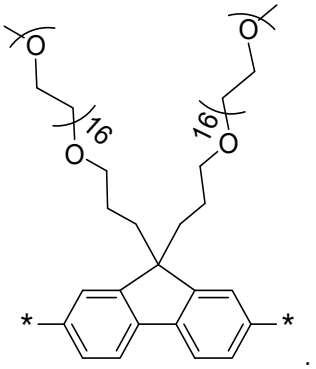




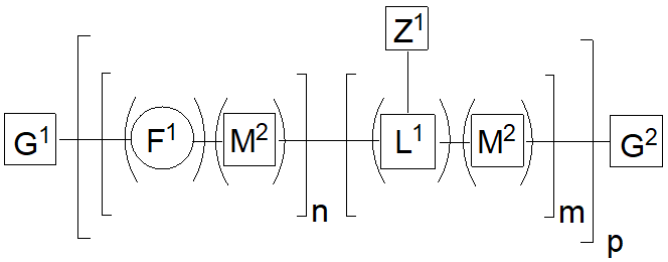








6. The water soluble light harvesting multichromophore according to claim 1, wherein the multichromophore has the structure of the following formula:



wherein:

F^1 is the fused tricyclic co-monomer;

M^1, M^2 and L^1 are independently an aryl or heteroaryl co-monomer;

Z^1 is a linked chemoselective functional group or a linked acceptor chromophore;

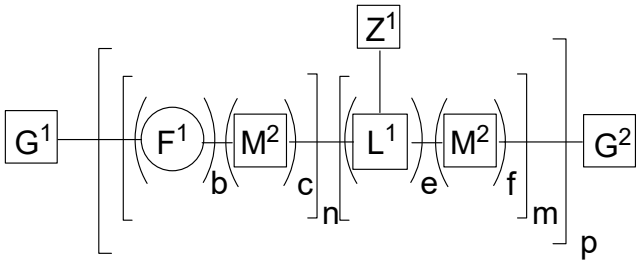
each n is independently an integer from 1 to 10,000;

each m is 0 or independently an integer from 1 to 10,000;

p is an integer from 1 to 100,000; and

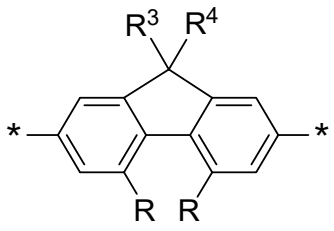
G^1 and G^2 are each independently selected from a terminal group, a π conjugated segment, a linker and a linked specific binding member.

7. The water soluble light harvesting multichromophore according to claim 6, wherein the multichromophore has the structure of formula (IV):



(IV).

8. The water soluble light harvesting multichromophore according to claim 7, wherein L^1 has the structure:



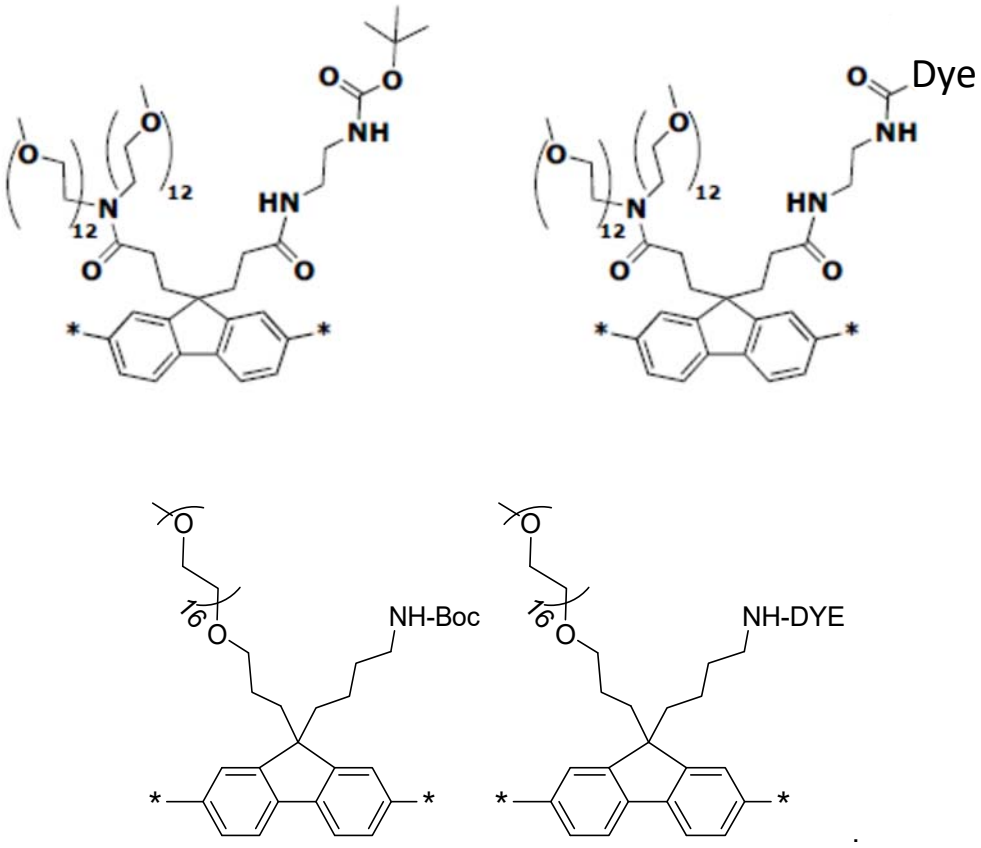
wherein:

R^3 is a non-ionic water soluble group (WSG);

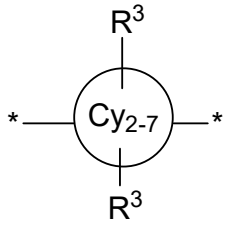
R^4 is L^2-Z^2 wherein L^2 is a linker and Z^2 is the chemoselective functional group or acceptor chromophore; and

each R is independently selected from H, WSG, halogen, alkoxy, substituted alkoxy, alkyl and substituted alkyl or wherein two R groups are optionally cyclically linked to provide a carbocyclic or heterocyclic ring.

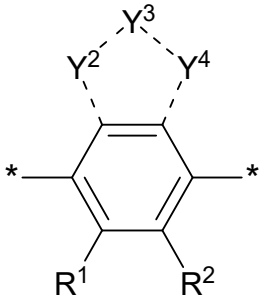
9. The water soluble light harvesting multichromophore according to claim 8, wherein L^1 has one of the following structures:



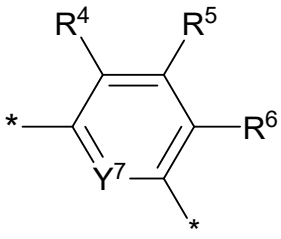
10. The water soluble light harvesting multichromophore according to claim 1, wherein the aryl or heteroaryl co-monomers are independently selected from one of formulae (XXIII)-(XXVI):



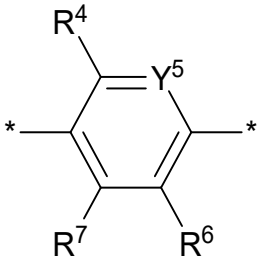
(XXIII)



(XXIV)



(XXV)



(XXVI)

wherein

Cy_{2-7} is an aryl or heteroaryl group comprising 2 to 7 fused and/or unfused rings;

Y^2, Y^3 and Y^4 are independently selected from $–CR^3$-, NR^3, N, O, S and –C(=O)- and together form a 5 or 6 membered fused aryl or heteraryl ring;

each R^3 is one or more ring substituents independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy substituted alkoxy and $–T^1$-Z^1;

R^1 and R^2 are independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1$-Z^1, or R^1 and R^2 together form a 5- or 6-membered fused aryl,heteroaryl ring, cycloalkyl or heterocycle which can be optionally substituted;

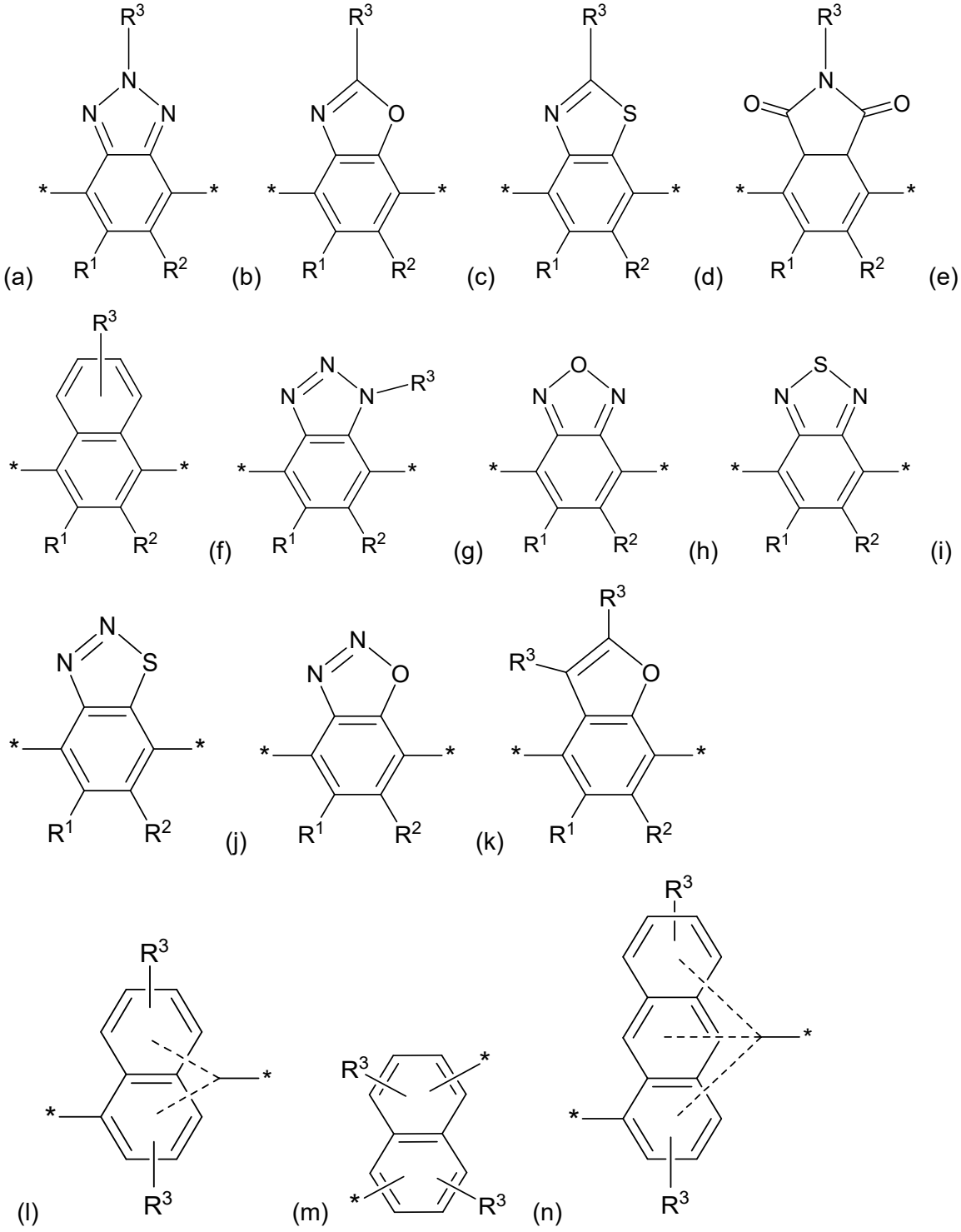
Y^5 is N or CR^5 and Y^7 is N or CR^7;

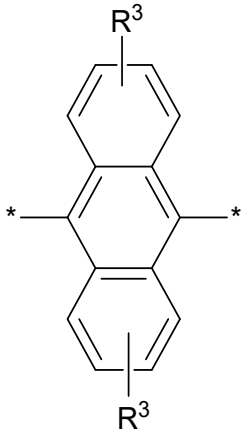
R^4-R^7 are independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1$-Z^1;

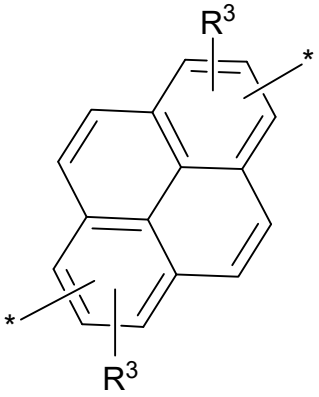
Z^1 is a chemoselective functional group or a linked signaling chromophore; and

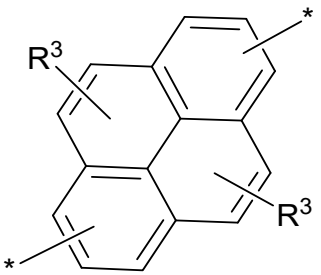
T^1 is a linker.

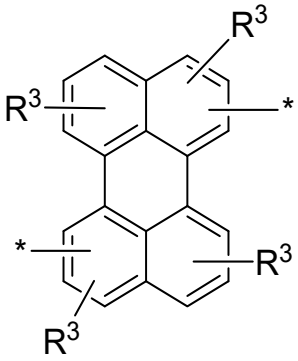
11. The water soluble light harvesting multichromophore according to claim 10, wherein the aryl or heteroaryl co-monomers are independently selected from one of the following structures (a) to (x):

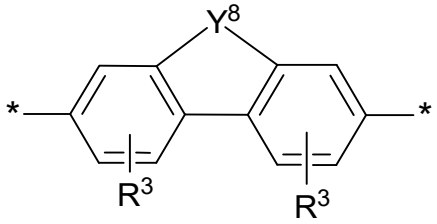


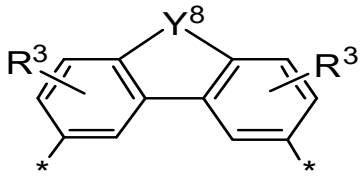
(o) 

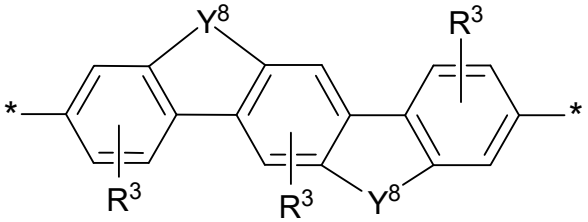
(p) 

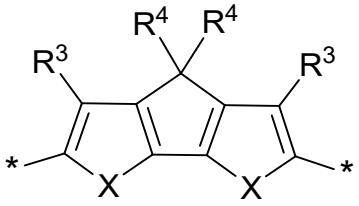
(q) 

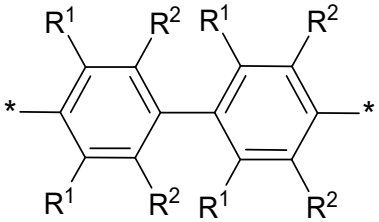
(r) 

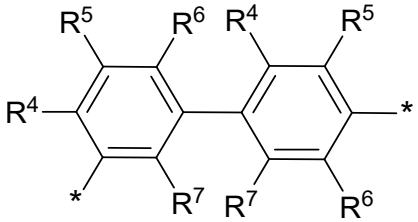
(s) 

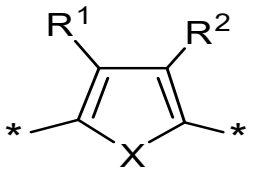
or 

(t) 

(u) 

(v) 

(w) 



(x)

wherein:

Y^8 is $C(R^3)_2$, $-C(R^3)_2C(R^3)_2-$, $-C(R^3)_2Si(R^3)_2-$, NR^3 or $Si(R^3)_2$;

X is S or O;

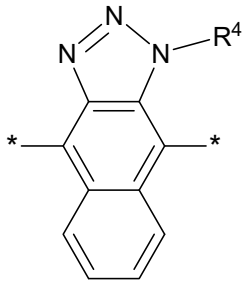
each R^3 is independently H, a water soluble group, amino, substituted amino, halogen, cyano, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1-Z^1$;

R^1 and R^2 are independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1-Z^1$, or R^1 and R^2 together form a 5- or 6-membered fused aryl, heteroaryl, cycloalkyl or heterocycle ring which can be optionally substituted;

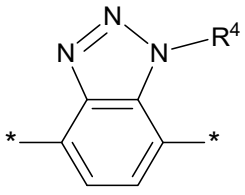
Z^1 is a chemoselective functional group or a linked signaling chromophore; and

T^1 is a linker.

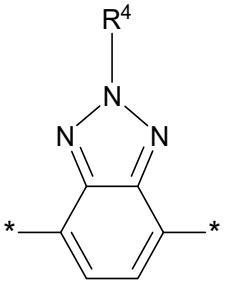
12. The water soluble light harvesting multichromophore according to claim 11, wherein the aryl or heteroaryl co-monomers are independently selected from one of the following structures (ba) to (cd):



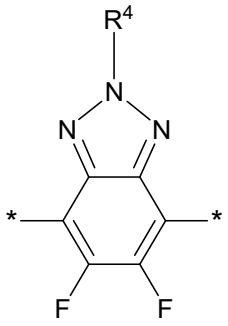
(ba)

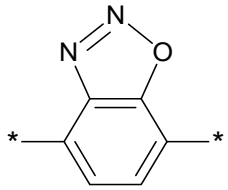


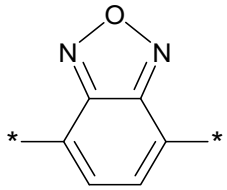
(bb)

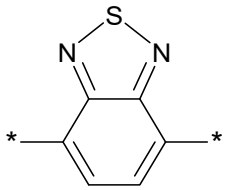


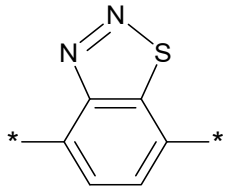
(bc)

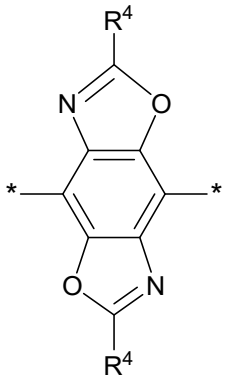
(bd) 

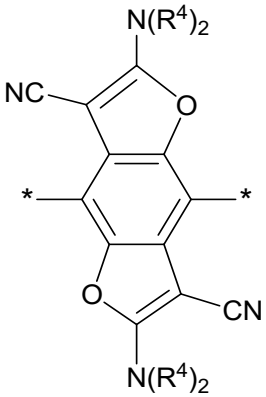
(be) 

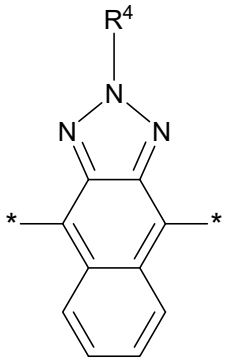
(bf) 

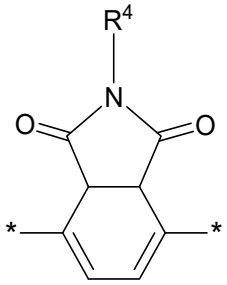
(bg) 

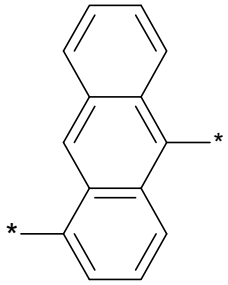
(bh) 

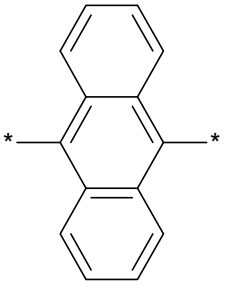
(bi) 

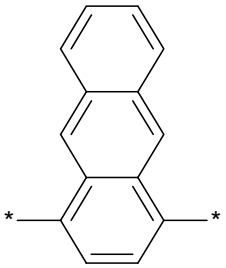
(bj) 

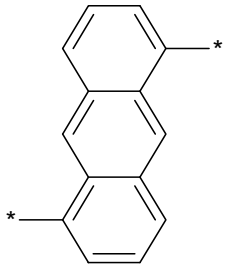
(bk) 

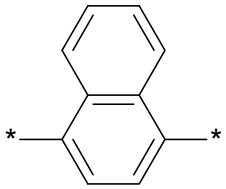
(bl) 

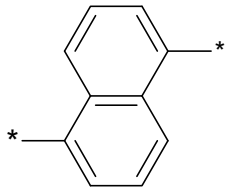
(bm) 

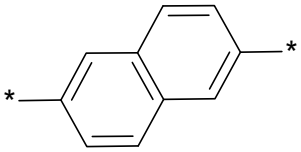
(bn) 

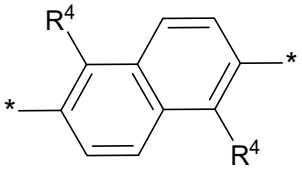
(bo) 

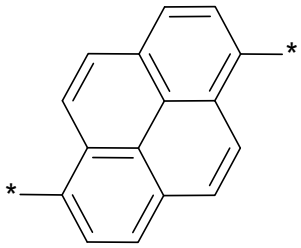
(bp) 

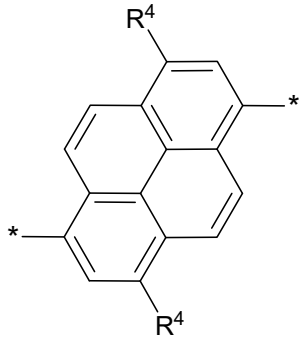
(bq) 

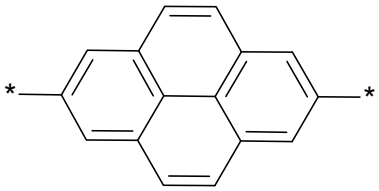
(br) 

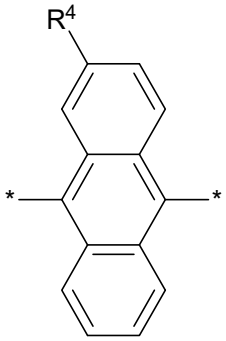
(bs) 

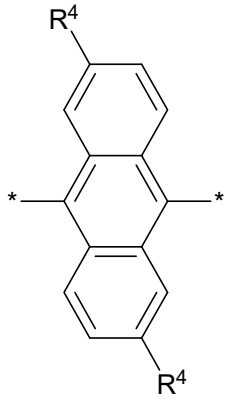
(bt) 

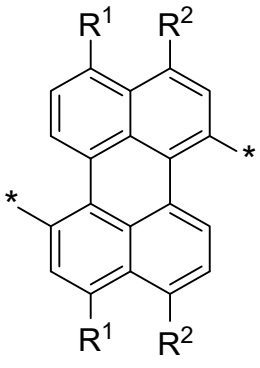
(bu) 

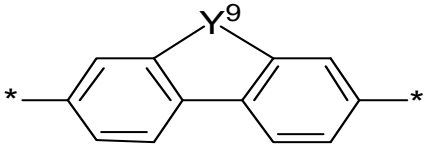
(bv) 

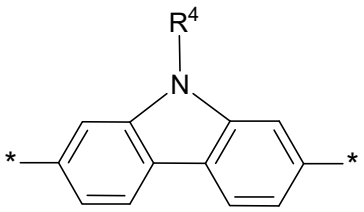
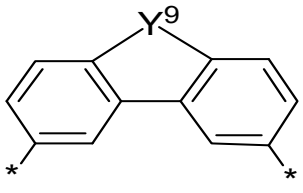
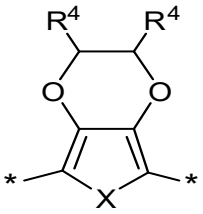
(bw) 

(bx) 

(by) 

(bz) 

(ca) 

(cb)  (cc)  (cd) 

wherein:

X is S or O;

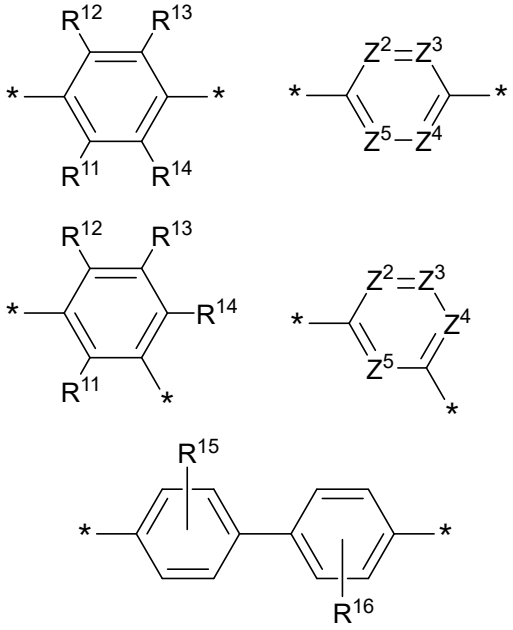
Y^9 is $C(R^4)_2$, $-C(R^4)_2C(R^4)_2-$ or $Si(R^4)_2$;

each R^4 is independently H, a water solubilizing group, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1-Z^1$; and

R^1 and R^2 are independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy and $–T^1-Z^1$, or R^1 and R^2 together form a 5- or 6-membered fused aryl or heteroaryl ring which can be optionally substituted.

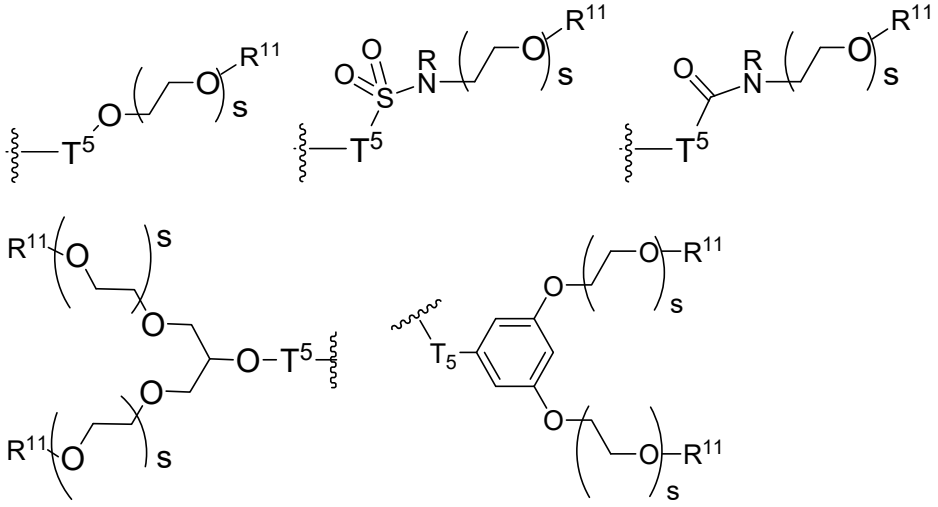
13. The water soluble light harvesting multichromophore according to claim 1, wherein the aryl or heteroaryl co-monomers are independently selected from a substituted or unsubstituted 1,4-phenyl, a substituted or unsubstituted 1,3-phenyl, a substituted or unsubstituted 4,4'-biphenyl, a substituted or unsubstituted 2,5-pyridyl, and a substituted or unsubstituted 2,6-pyridyl.

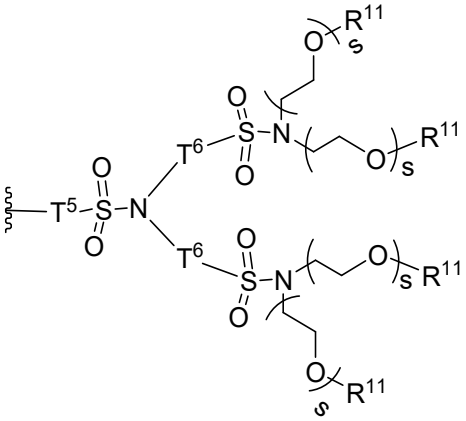
14. The water soluble light harvesting multichromophore according to claim 13, wherein the aryl or heteroaryl co-monomer is selected from one of the following structures:

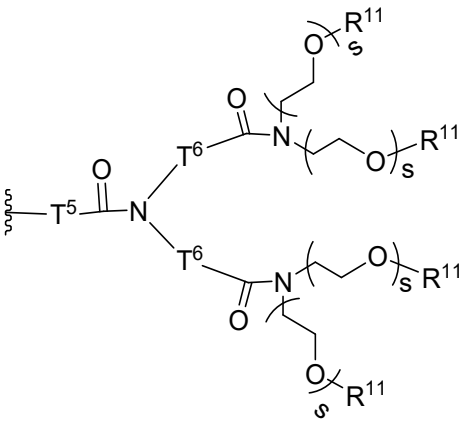


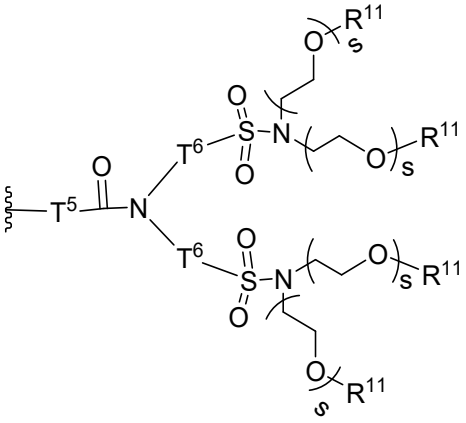
wherein Z^2-Z^5 are each independently CR or N, where at least one Z^2-Z^5 is N; and each R and each R^{11}-R^{16} are independently selected from the group consisting of hydrogen, water solubilizing group, halogen, cyano, alkoxy, substituted alkoxy, alkyl and substituted alkyl.

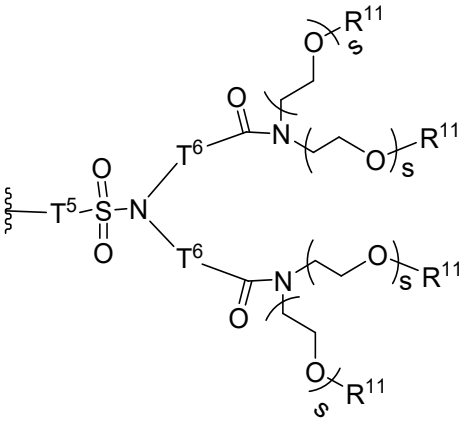
15. The water soluble light harvesting multichromophore according to claim 1, wherein each co-monomer is substituted with a WSG independently selected from one of the following structures:

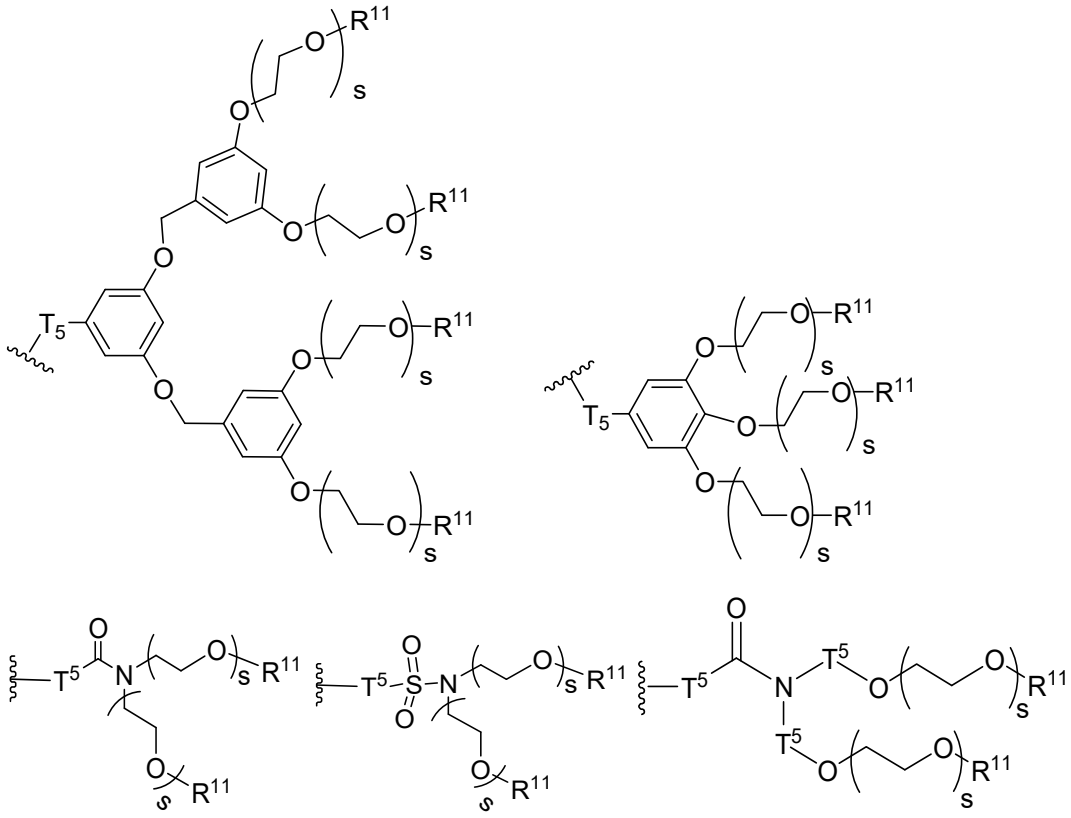












wherein:

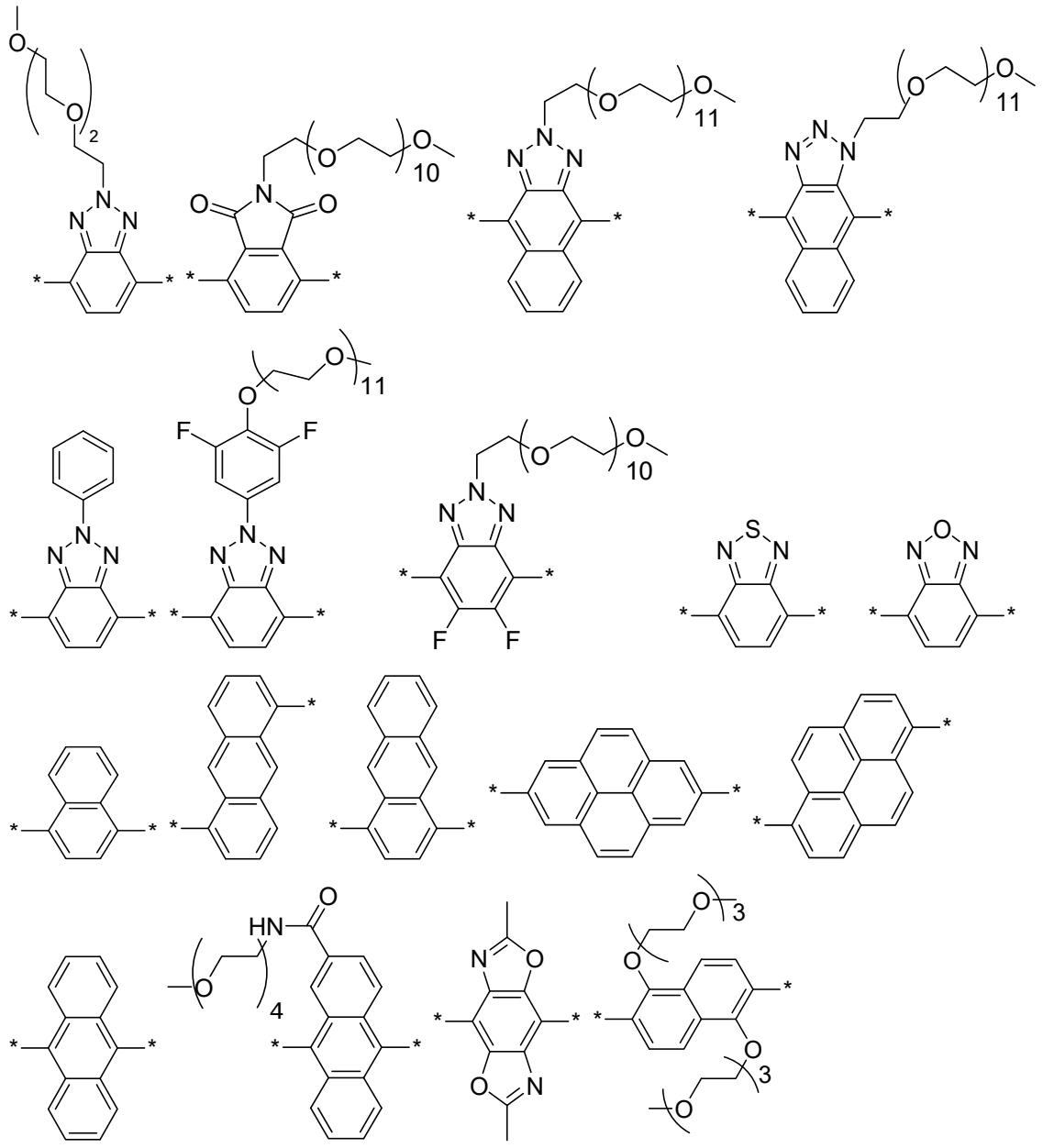
T^5 is an optional linker;

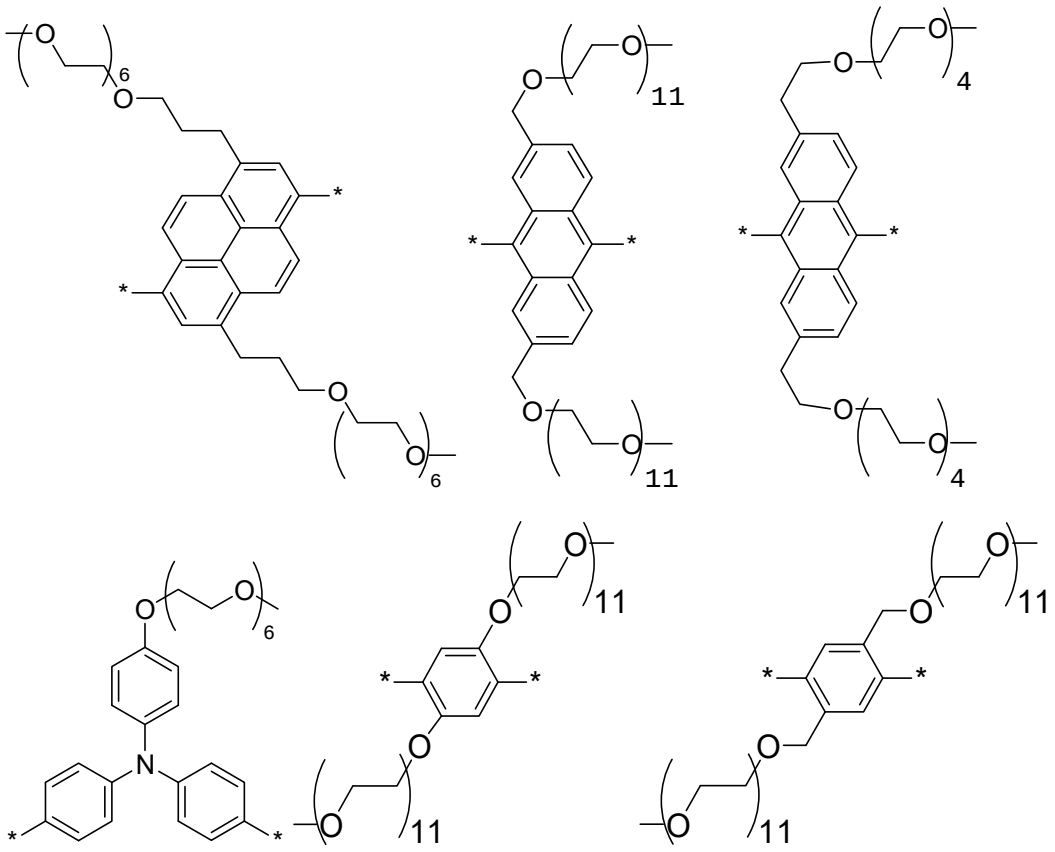
each T^6 is an linker;

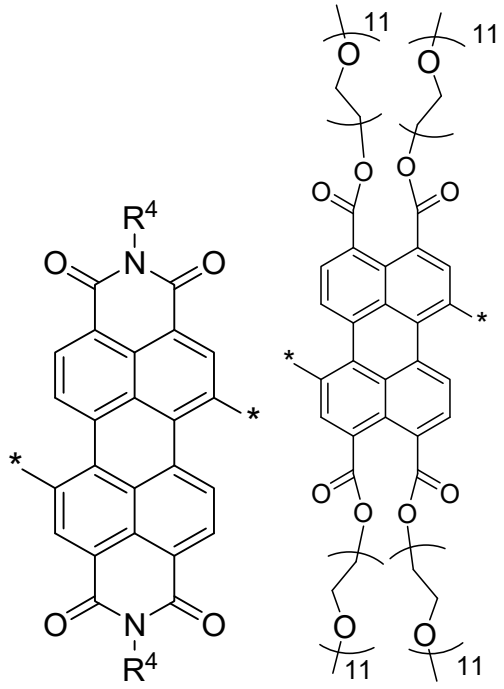
R^{11} and R are independently H, alkyl or substituted alkyl; and

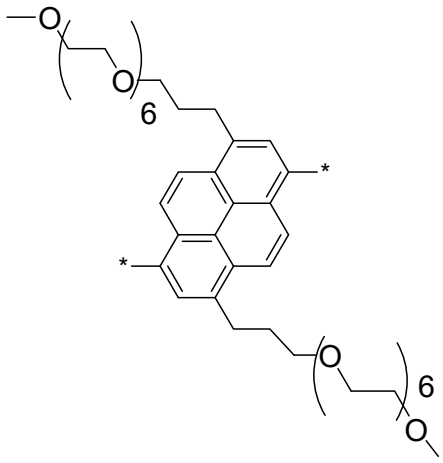
each s is an integer from 1 to 50.

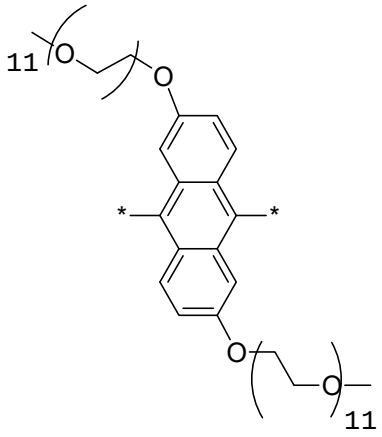
16. The water soluble light harvesting multichromophore according to claim 1, wherein the aryl or heteroaryl co-monomers are independently selected from one of the following structures:

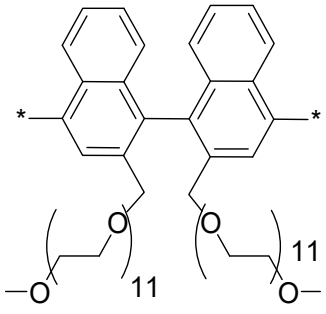


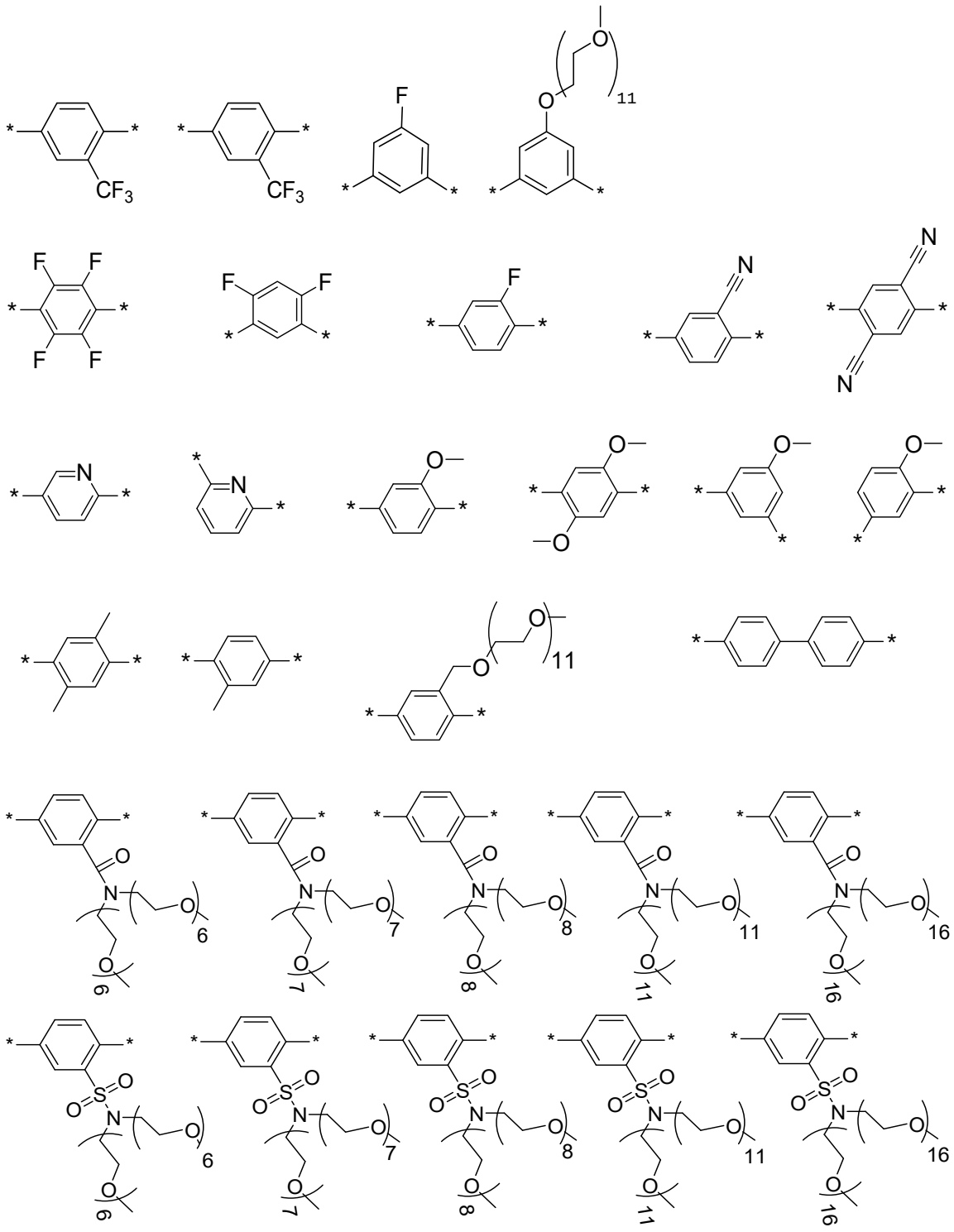












wherein:

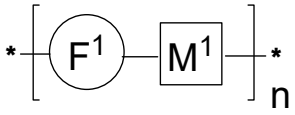
each R^4 is independently selected from H, halogen, alkyl, substituted alkyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, acyl, substituted acyl, sulfonic acid, cyano, alkoxy, substituted alkoxy, and $-T^1-Z^1$;

Z^1 is a chemoselective functional group or a linked signaling chromophore; and

T^1 is a linker.

17. A polymeric tandem dye comprising:

a water soluble light harvesting multichromophore comprising a conjugated segment having the structure of formula (I):



(I)

wherein:

F^1 is a fused tricyclic co-monomer substituted with a water soluble group (WSG);

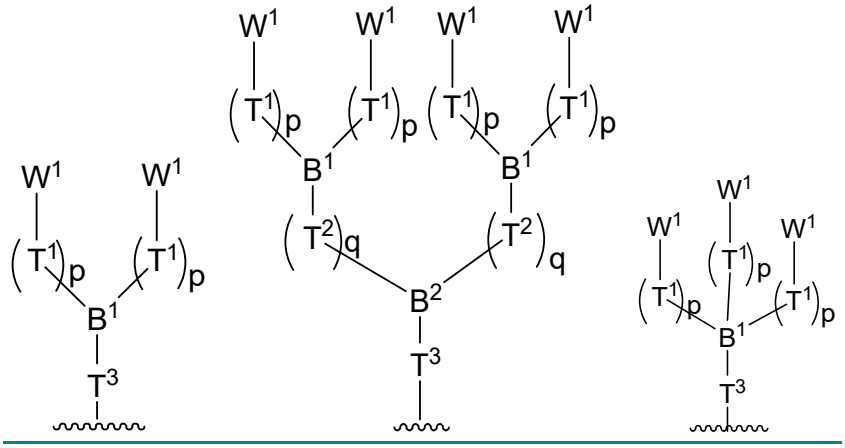
M^1 is an aryl or heteroaryl co-monomer;

n is an integer from 1 to 100,000; and

* denotes a site for covalent attachment to the unsaturated backbone of a conjugated polymer or an end group;

wherein at least one of F^1 and M^1 is substituted with a branched non-ionic water soluble group (WSG) comprising two or more water soluble polymers each having 6-50 monomeric units;

wherein the branched non-ionic water soluble group is capable of imparting solubility in water in excess of 50 mg/mL to the multichromophore and has one of the following formulae:



wherein:

each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

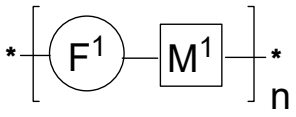
T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–; and

a signaling chromophore covalently linked to the multichromophore in energy-receiving proximity therewith.

18. An aggregation-resistant labelled specific binding member comprising:

a water soluble light harvesting multichromophore comprising a conjugated segment having the structure of formula (I):



(I)

wherein:

F^1 is a fused tricyclic co-monomer substituted with a water soluble group (WSG);

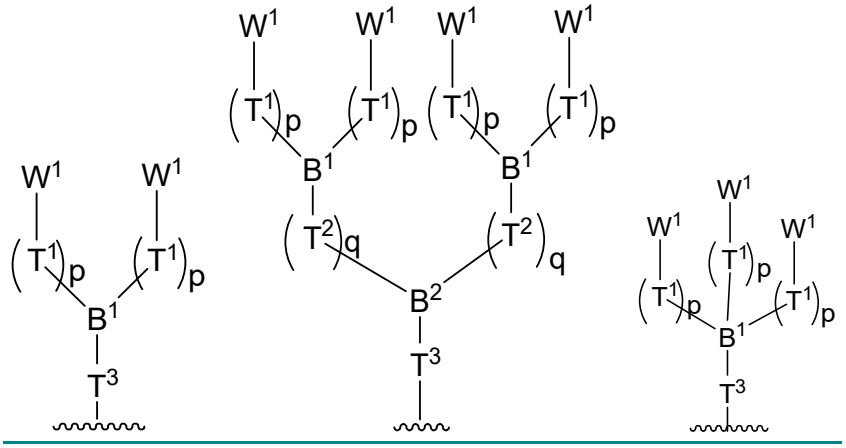
M^1 is an aryl or heteroaryl co-monomer;

n is an integer from 1 to 100,000; and

* denotes a site for covalent attachment to the unsaturated backbone of a conjugated polymer or an end group;

wherein at least one of F^1 and M^1 is substituted with a branched non-ionic water soluble group (WSG) comprising two or more water soluble polymers each having 6-50 monomeric units;

wherein the branched non-ionic water soluble group is capable of imparting solubility in water in excess of 50 mg/mL to the multichromophore and has one of the following formulae:



wherein:

each B^1 and B^2 are independently a branching group selected from the group consisting of CH, N, C(=O)N, SO_2N, a tri-substituted aryl group, a tetra-substituted aryl group, and a tri-substituted heteroaryl group;

each W^1 is independently a water soluble polymer comprising 6-24 monomeric units;

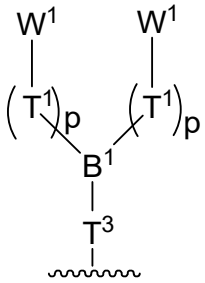
T^3 is an optional linker to the fused 6-5-6 tricyclic co-monomer; and

each p and q are independently 0 or 1, wherein if present, each T^1 and each T^2 are independently a linker, wherein each T^1 is independently selected from the group consisting of $(CH_2)_n$–O–, –O–$(CH_2)_n$–, –$(CH_2)_n$–, and –O–; and

a specific binding member covalently linked to the multichromophore.

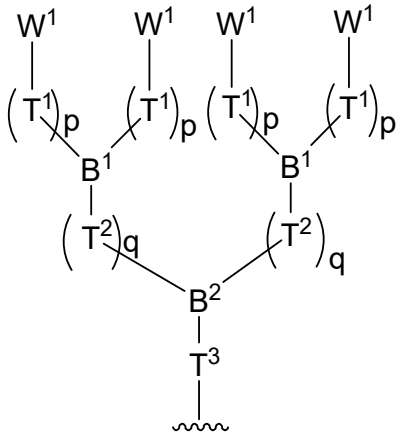
19. The labelled specific binding member according to claim 18, further comprising a signaling chromophore covalently linked to the multichromophore in energy-receiving proximity therewith.

20. The water soluble light harvesting multichromophore according to claim 1, wherein the branched non-ionic water soluble group (WSG) has the formula:



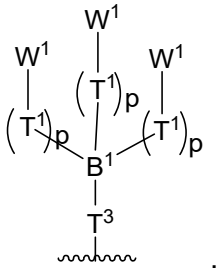
.

21. The water soluble light harvesting multichromophore according to claim 1, wherein the branched non-ionic water soluble group (WSG) has the formula:



.

22. The water soluble light harvesting multichromophore according to claim 1, wherein the branched non-ionic water soluble group (WSG) has the formula:



.