Ink composition containing a particular type of dye, and corresponding ink jet printing process

EP1486539

Publication Title:

Self-assembling dyes

Abstract:

A novel dye according to formula (I): <CHEM> capable of self-assembling thus forming supra-molecular structures. These self-assembling dyes may be advantageously used in an ink-jet ink for improving the stability of ink-jet ink images to light fading.

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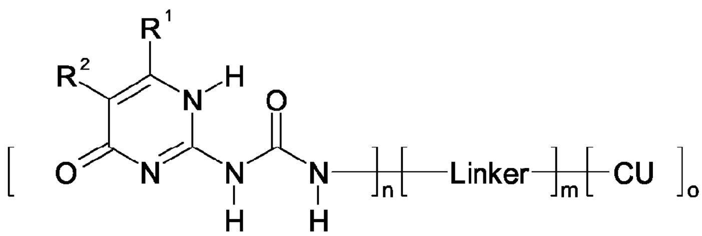
(54) **Self-assembling dyes**

(57) A novel dye according to formula (I):



Formula (I)

capable of self-assembling thus forming supra-molecular structures. These self-assembling dyes may be advantageously used in an ink-jet ink for improving the stability of ink-jet ink images to light fading.

EP 1 486 539 A2

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a particular type of novel dye. It further relates to ink-jet compositions and ink-jet printing processes using these dyes, and to an ink-jet printing apparatus provided with an ink cartridge containing such a dye.

BACKGROUND OF THE INVENTION

[0002] In the majority of applications printing proceeds by pressure contact of an ink-loaden printing form with an ink-receiving material which is usually plain paper. The most frequently used impact printing technique is known as lithographic printing based on the selective acceptance of oleophilic ink on a suitable receptor.

[0003] In recent times however so-called non-impact printing systems have replaced classical pressure-contact printing to some extent for specific applications. A survey is given e.g. in the book "Principles of Non Impact Printing" by Jerome L. Johnson (1986), Palatino Press, Irvine, CA 92715, USA.

[0004] Among non-impact printing techniques ink jet printing has become a popular technique because of its simplicity, convenience and low cost. Especially in those instances where a limited edition of the printed matter is needed ink jet printing has become a technology of choice. A recent survey on progress and trends in ink jet printing technology is given by Hue P. Le in *Journal of Imaging Science and Technology* Vol. 42 (1), Jan/Febr 1998.

[0005] In ink jet printing tiny drops of ink fluid are projected directly onto an ink receptor surface without physical contact between the printing device and the receptor. The printing device stores the printing data electronically and controls a mechanism for ejecting the drops image-wise. Printing is accomplished by moving the print head across the paper or vice versa. Early patents on ink jet printers include US 3,739,393, US 3,805,273 and US 3,891,121.

[0006] The jetting of the ink droplets can be performed in several different ways. In a first type of process a continuous droplet stream is created by applying a pressure wave pattern. This process is known as continuous ink jet printing. In a first embodiment the droplet stream is divided into droplets that are electrostatically charged, deflected and recollected, and into droplets that remain uncharged, continue their way undeflected, and form the image. Alternatively, the charged deflected stream forms the image and the uncharged undeflected jet is recollected. In this variant of continuous ink jet printing several jets are deflected to a different degree and thus record the image (multideflection system).

[0007] According to a second process the ink droplets can be created "on demand" ("DOD" or "drop on demand" method) whereby the printing device ejects the droplets only when they are used in imaging on a receiver thereby avoiding the complexity of drop charging, deflection hardware, and ink recollection. In drop-on-demand the ink droplet can be formed by means of a pressure wave created by a mechanical motion of a piezoelectric transducer (so-called "piezo method"), or by means of discrete thermal pushes (so-called "bubble jet" method, or "thermal jet" method).

[0008] Ink compositions for ink jet typically include following ingredients : dyes or pigments, water and/or organic solvents, humectants such as glycols, detergents, thickeners, polymeric binders, preservatives, etc.. It will be readily understood that the optimal composition of such an ink is dependent on the ink jetting method used and on the nature of the substrate to be printed. The ink compositions can be roughly divided in :

- water based ; the drying mechanism involves absorption, penetration and evaporation;
- oil based ; the drying involves absorption and penetration;
- solvent based ; the drying mechanism involves primarely evaporation;
- hot melt or phase change : the ink vehicle is liquid at the ejection temperature but solid at room temperature ; drying is replaced by solidification;
- UV-curable ; drying is replaced by polymerization.

[0009] It is known that the ink-receiving layers in ink-jet recording elements must meet different stringent requirements :

- The ink-receiving layer should have a high ink absorbing capacity, so that the dots will not flow out and will not be expanded more than is necessary to obtain a high optical density.
- The ink-receiving layer should have a high ink absorbing speed (short ink drying time) so that the ink droplets will not feather if smeared immediately after applying.
- The ink dots that are applied to the ink-receiving layer should be substantially round in shape and smooth at their peripheries. The dot diameter must be constant and accurately controlled.
- The receiving layer must be readily wetted so that there is no "puddling", i.e. coalescence of adjacent ink dots,

and an earlier absorbed ink drop should not show any "bleeding", i.e. overlap with neighbouring or later placed dots.

- Transparent ink-jet recording elements must have a low haze-value and be excellent in transmittance properties.
- After being printed the image must have a good resistance regarding waterfastness, lightfastness, and good endurance under severe conditions of temperature and humidity.
- The ink jet recording element may not show any curl or sticky behaviour if stacked before or after being printed.
- The ink jet recording element must be able to move smoothly through different types of printers.

[0010] All these properties are often in a relation of trade-off. It is difficult to satisfy them all at the same time.

[0011] It is also known that dyes used in inks for ink jet printing must meet different stringent requirements. For example they desirably provide sharp, non-feathered images having good waterfastness,solvent fastness, lightfastness and optical density. Their solubility must be fine-tuned to the vehicle they are dissolved in. Preferably they have high molecular extinction coefficients. In spite of the many dyes that already exist for application in ink jet inks, there is still a continuous search for novel dyes and especially for dyes with an improved lightfastness and stability towards (singlet) oxygen, ozone and air pollutants such as sulphur oxides (SOx) and nitrogen oxides (NOx).

OBJECTS OF THE INVENTION

[0012] It is an object of the present invention to provide novel dyes for producing ink-jet images exhibiting improved light-fastness.

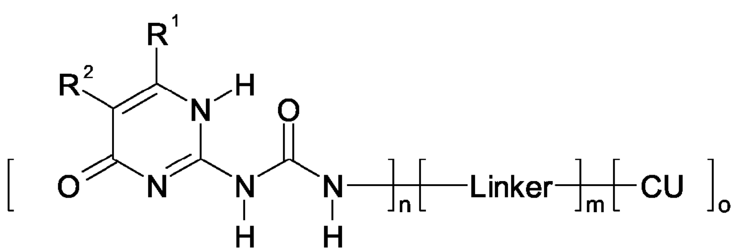
[0013] It is a further object of the present invention to provide an ink jet printing process using these inks.

[0014] Further objects of the invention will become clear from the detailed description hereinafter.

SUMMARY OF THE INVENTION

[0015] It has been found that the self-assembling dyes represented by formula (I) can be used to construct supramolecular dye systems with improved properties such as light fastness, water and solvent fastness.

[0016] Objects of the present invention are realized by providing a self-assembling dye according to formula (I):



Formula (I)

wherein

'Linker' represents any linking group;

'CU' means any chromophore group selected from the group consisting of an azo dye with a molar extinction coefficient larger than 10^3 l.mol^{-1}.cm^{-1}, an anthraquinone dye, a (poly)methine dye, an azomethine dye, a disazo dye, a carbonium dye, a styryl dye, a stilbene dye, a phthalocyanine dye, a coumarin dye, an aryl-carbonium dye, a nitro dye, a naphtholactam dye, a dioxazine dye, a flavin dye and a formazan dye;

n and o are the same or different and are integers having a value of at least 1; m can be zero or any integer having a value of at least 1;

n and o are the same or different and are integers having a value of at least 1; m can be zero or any integer having a value of at least 1;

R^1 and R^2 are the same or different and represent hydrogen, a halogen, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted thioalkoxy group, a substituted or unsubstituted sulphoxy group, a substituted or unsubstituted sulphone group, a substituted or unsubstituted amino group, a nitrile group, a substituted or unsubstituted, saturated or unsaturated alkyl group, a substituted or unsubstituted acyl group, a substituted or unsubstituted sulphonyl group, a substituted or unsubstituted phosphoryl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted aralkyl group, a heterocyclic group, a CU group, or R^1 and R^2 represent the necessary atoms to form a ring system

DETAILED DESCRIPTION OF THE INVENTION

Self-assembly

[0017] In the past the focus was largely on the *reaction* of molecules rather than on their *interaction.* Increasingly, attention has been given to the formation of molecular assemblies that are held together by a range of relatively weak intermolecular interactions. These non-covalent interactions are often dominated by hydrogen bonding and, if aromatic components are present, by π-cloud interactions. Weak forces such as dispersion, polarisation and charge-transfer interactions - combinations of which make up van der Waals forces - may act. Stronger interactions such as electrostatic interactions are often of central importance in molecular recognition.

[0018] With the development of supramolecular chemistry, there has been a concomitant shift in the mind-set of chemists working in the area. This has involved a change in focus from single molecules, often constructed step by step via the formation of direct covalent linkages, towards molecular assemblies, with their usual non-covalent weak intermolecular contacts (J.-M. Lehn, Angew. Chem. Int. Ed. Engl.,1990, 29, 1304). The properties of these supramolecular systems are clearly different form the properties of its molecular components. Supramolecular chemistry is focusing on molecular design for achieving complementarity between single molecules. In the present context, self-assembly may be defined as the process by which a supramolecular species forms spontaneously from its components. For the majority of synthetic systems it appears to be a beautifully simple convergent process, giving rise to the assembled target in a straightforward manner. Self-assembly is very far from a unique feature of supramolecular systems - it is ubiquitous throughout life chemistry. Biological systems aside, self-assembly is also commonplace throughout chemistry.

[0019] According to the present invention self-assembling dyes are used to construct supramolecular dye-systems with improved properties such as lightfastness, water and solvent fastness. A distinctive feature of using weak, non-covalent forces in molecular assemblies is that such interactions are normally readily reversible so that the final product is in thermodynamic equilibrium with its components (usually via its corresponding partially assembled intermediates). This leads to an additional property of most supramolecular systems : they have an in-built capacity for error correction not available to fully covalent systems. It needs to be noted that supramolecular systems may also form under kinetic rather than thermodynamic control. This situation will tend to be more likely for larger supramolecular assemblies incorporating many intermolecular contacts, especially when moderately rigid components are involved.

[0020] According to the present invention new self-assembling dyes with improved lightfastness properties have been developed whereby the process of molecular recognition and self-assembly through the formation of intermolecular hydrogen bonds is induced through the removal of the ink vehicle. This process is called "Evaporation Induced Self-Assembly (EISA)". EISA has been used to prepare a photosensitive thin-film mesophase containing a photoacid generator (Science, Vol. 290, 6 October 2000, 107-111) and for rapid prototyping of patterned functional nanostructures (Nature, Vol.405, 4 May 2000, 56-60). In liquid based inks EISA occurs through evaporation of the liquid. In phase change inks this process occurs through solidification of the ink. As long as the self-assembling dyes are dissolved in the ink no or partial self-assembly occurs because of the formation of hydrogen bonds with the ink vehicle. Once the ink vehicle (or one of the ink vehicles) is removed through for example evaporation, self-assembly of the dyes is induced resulting in supramolecular structures. In these assemblies the integrity of the individual component molecules normally remains largely intact:that is, the wave functions of the respective molecular components remain largely separate on complex formation. However, after the initial self-assembly process through hydrogen bonding has started, secondary interactions may occur such as π-stacking resulting in more rigid structures with different physical properties such as shifts in spectral absorption and molecular extinction coefficient, extra energy levels for thermal relaxation, etc. Due to multiple intermolecular hydrogen bonding the molecule can absorb UV-radiation transforming it into vibrational energy and/or heat through efficient radiationless deactivation pathways, as described in J. Photochem.Photobiol.A: Chem. 1998,41,p.227.

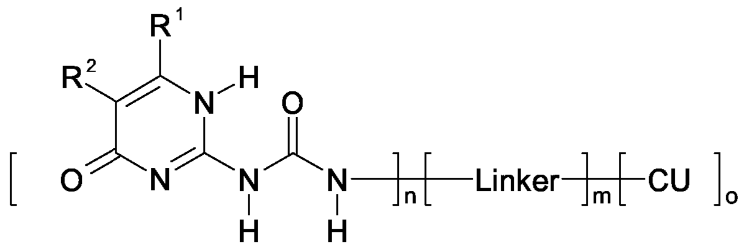
[0021] According to the present invention the self-assembly process can occur between the self-assembling dyes themselves but also between (a) self-assembling dye molecule(s) including the self-assembling dye according to formula (I) and (a) complementary multiple H-donor/acceptor molecule(s) lacking the dye-fragment. For each possible case, the association constant of the assembly reaction K_{ass}, determined by ^{1}H-NMR in $CDCl_3$, is at least 2.5 M^{-1}, more preferably at least 10^2 M^{-1}, and most preferably at least 10^5 M^{-1}.

[0022] Hydrogen bonds are a special type of electrostatic interaction and can be described as an attractive interaction between a proton donor and a proton acceptor. According to the present invention the definition of a hydrogen bond presented by Pimentel and McClellan (G.C. Pimentel, A.L. McClellan, The Hydrogen Bond, Freeman, San Francisco, 1960) is used, which is:

A hydrogen bond exists between a functional group A-H and an atom or a group of atoms B in the same or a different molecule when:

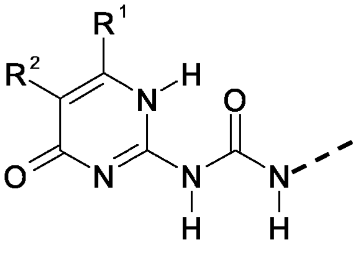
(a) there is evidence of bond formation (association or chelation);
(b) there is evidence that this new bond linking A-H and B specifically involves the hydrogen atom already bonded to A.

[0023] Both the donor (A) and the acceptor (B) atoms have electronegative character, with the proton involved in the hydrogen bond being shared between the electron pairs on A and B. The inherent directionality of hydrogen bonds makes them ideal for use in achieving complementarity in supramolecular systems.
[0024] Objects of the present invention are realized with a self-assembling dye according to formula (I):



Formula (I)

wherein
'Linker' represents any linking group;
'CU' means any chromophore group selected from the group consisting of an azo dye with a molar extinction coefficient larger than 10^3 l.mol^{-1}.cm^{-1}, an anthraquinone dye, a (poly)methine dye, an azomethine dye, a disazo dye, a carbonium dye, a styryl dye, a stilbene dye, a phthalocyanine dye, a coumarin dye, an aryl-carbonium dye, a nitro dye, a naphtholactam dye, a dioxazine dye, a flavin dye and a formazan dye;
n and o are the same or different and are integers having a value of at least 1; m can be zero or any integer having a value of at least 1;
R^1 and R^2 are the same or different and represent hydrogen, a halogen, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted thioalkoxy group, a substituted or unsubstituted sulphoxy group, a substituted or unsubstituted sulphone group, a substituted or unsubstituted amino group, a nitrile group, a substituted or unsubstituted, saturated or unsaturated alkyl group, a substituted or unsubstituted acyl group, a substituted or unsubstituted sulphonyl group, a substituted or unsubstituted phosphoryl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted aralkyl group, a heterocyclic group, a CU group, or R^1 and R^2 represent the necessary atoms to form a ring system.
[0025] In the self-assembling dyes according to the present invention the SAU is an ureidopyrimidone group represented by formula (II):



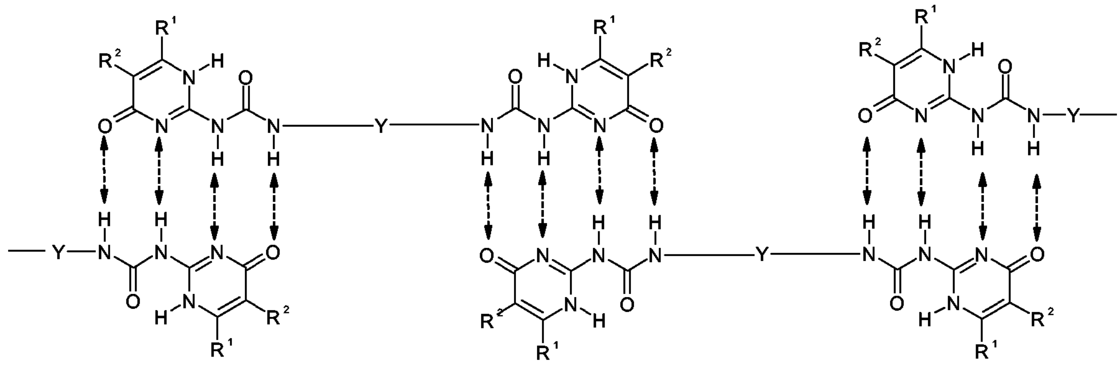
Formula (II)

wherein,
R^1 and R^2 are the same or different and represent hydrogen, a halogen, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted thioalkoxy group, a substituted or unsubstituted sulphoxy group, a substituted or unsubstituted sulphone group, a substituted or unsubstituted amino group, a nitrile group, a substituted or unsubstituted, saturated or unsaturated alkyl group, a substituted or unsubstituted acyl group, a substituted or unsubstituted sulphonyl

group, a substituted or unsubstituted phosphoryl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted aralkyl group, a heterocyclic group, a CU group, or R^1 and R^2 represent the necessary atoms to form a ring system.

[0026] The dyes according to the present invention can be prepared using synthetic methods known to those who are skilled in the art of organic synthesis. By way of example the synthesis of several dyes according to the present invention is described in the Examples.

[0027] A representative example of a dye system is shown in System Formula 1.



System Formula 1.

wherein,

Y represents CU or Z-CU;

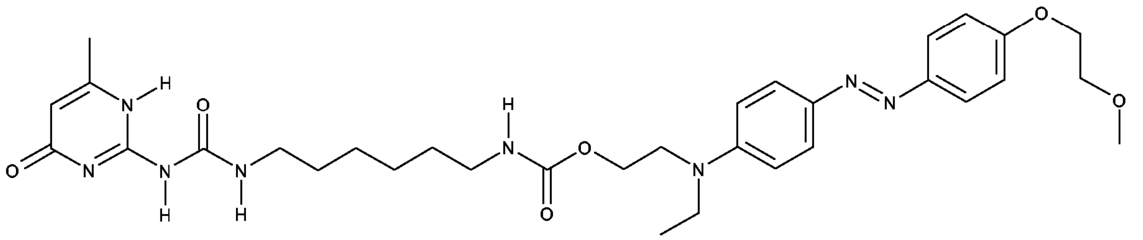
CU means any chromophore group absorbing between 200nm and 2000nm, such as an azo dye, an anthraquinone dye, a (poly)methine dye, an azomethine dye, a polyene dye, a pyrene dye, a disazo dye, a carbonium dye, a styryl dye, a stilbene dye, a phthalocyanine dye, a coumarin dye, an aryl-carbonium dye, a nitro dye, a naphtholactam dye, a dioxazine dye, a flavin dye, a formazan dye;

R^1 and R^2 are the same or different and represent hydrogen, a halogen, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted thioalkoxy group, a substituted or unsubstituted sulphoxy group, a substituted or unsubstituted sulphone group, a substituted or unsubstituted amino group, a nitrile group, a substituted or unsubstituted, saturated or unsaturated alkyl group, a substituted or unsubstituted acyl group, a substituted or unsubstituted sulphonyl group, a substituted or unsubstituted phosphoryl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted aralkyl group, a heterocyclic group, a CU group, or R^1 and R^2 represent the necessary atoms to form a ring system; and

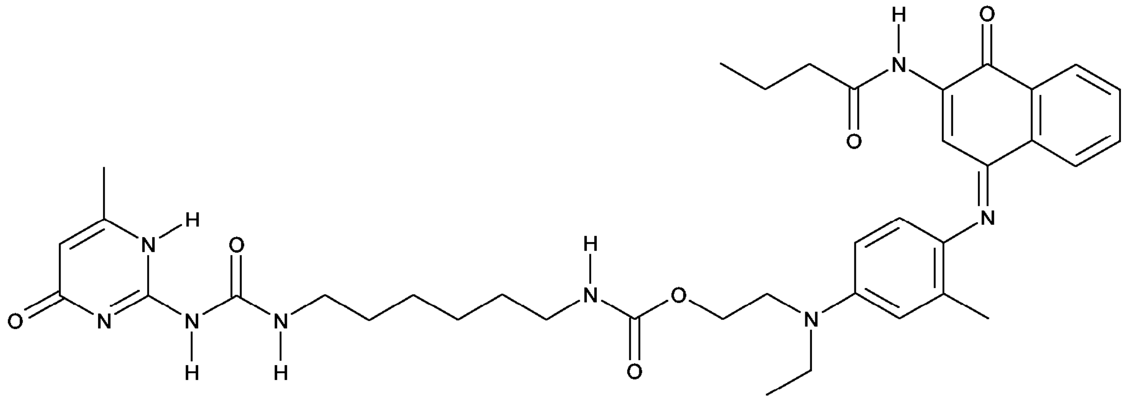
Z represents any linking group.

[0028] Actual examples of self-assembling dyes according to the present invention are shown in Table 1.

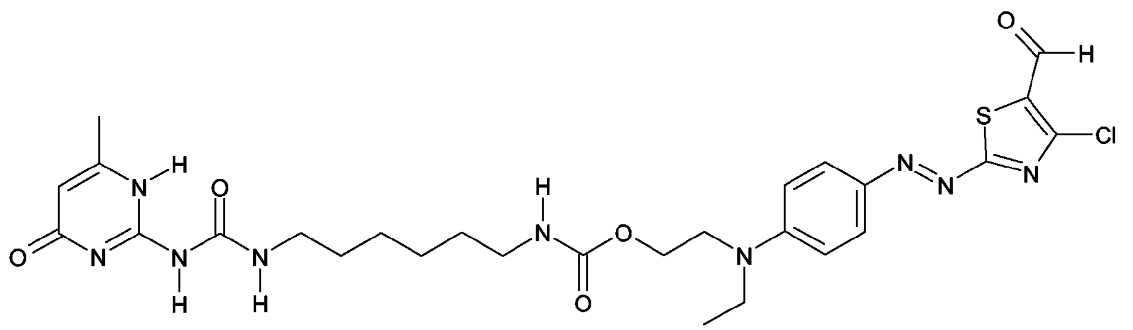
Table 1.



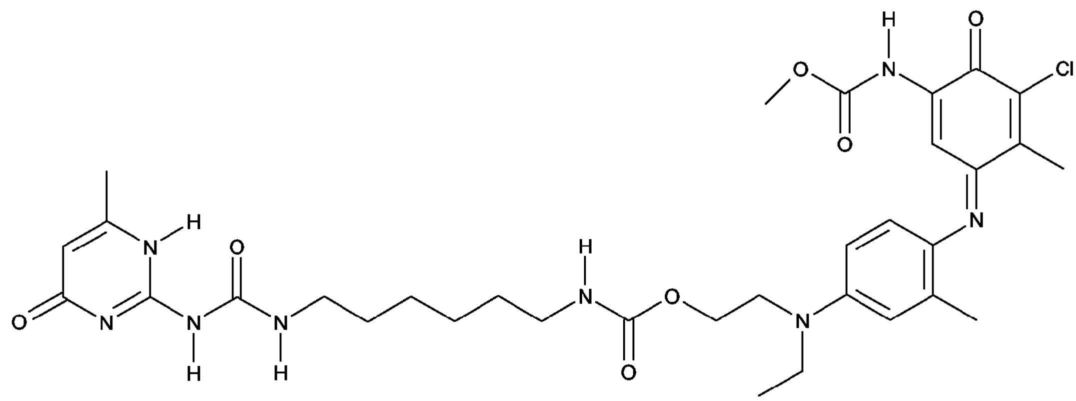
Dye 1



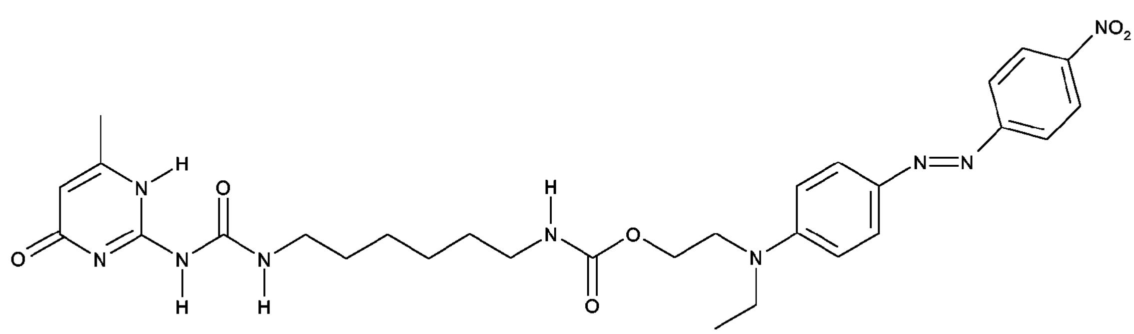
Dye 2



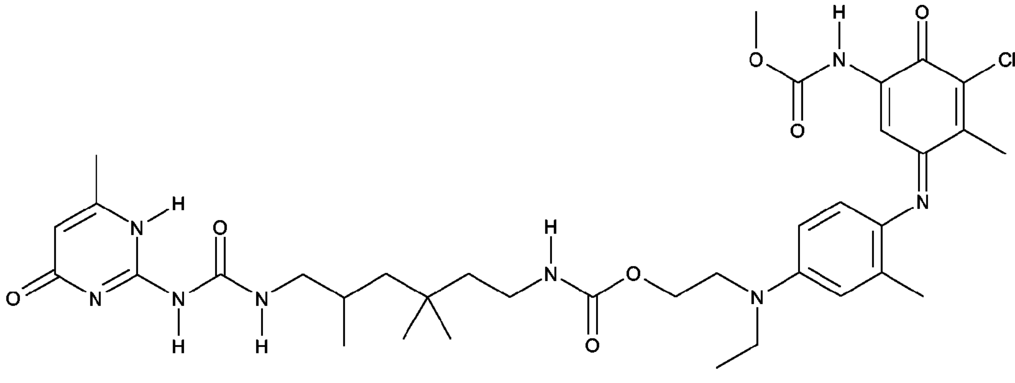
Dye 3



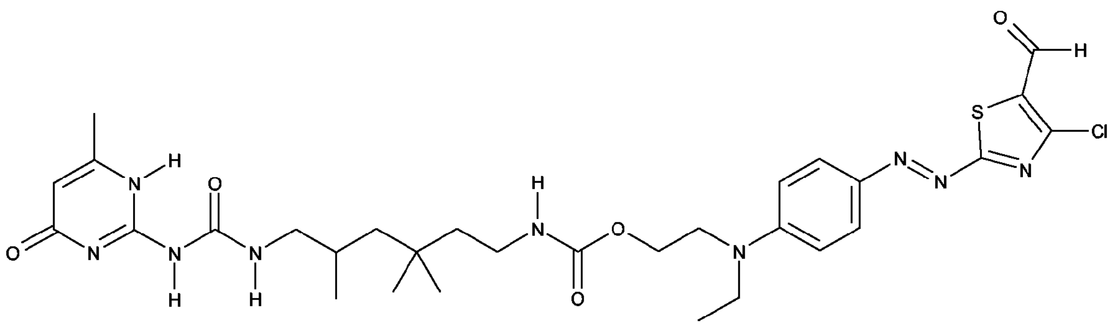
Dye 4



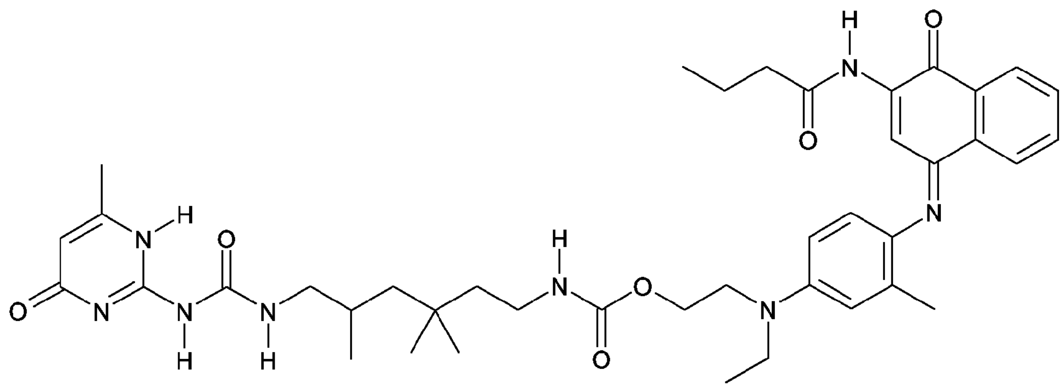
Dye 5



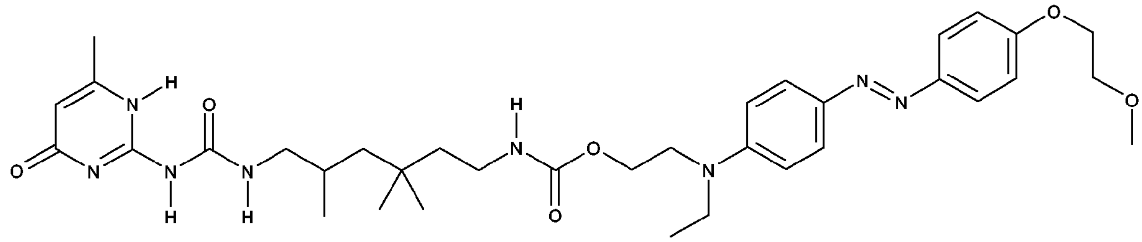
Dye 6



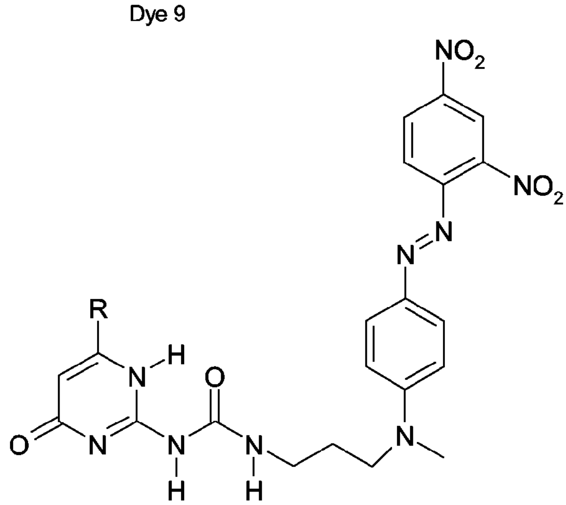
Dye 7



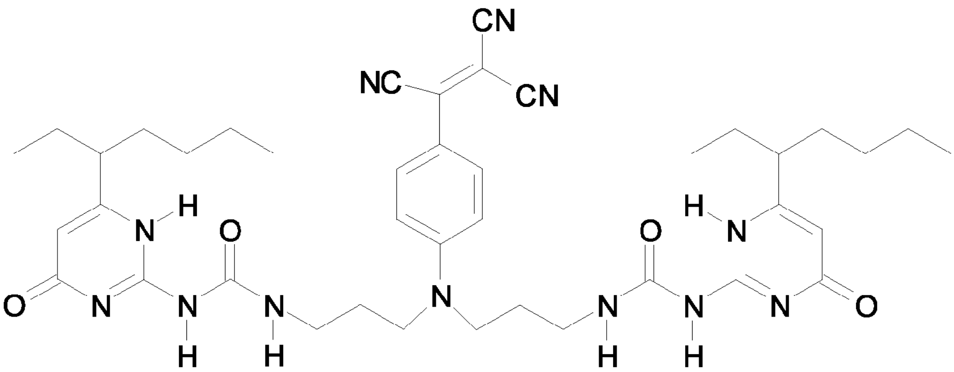
Dye 8



Dye 9



Dye 10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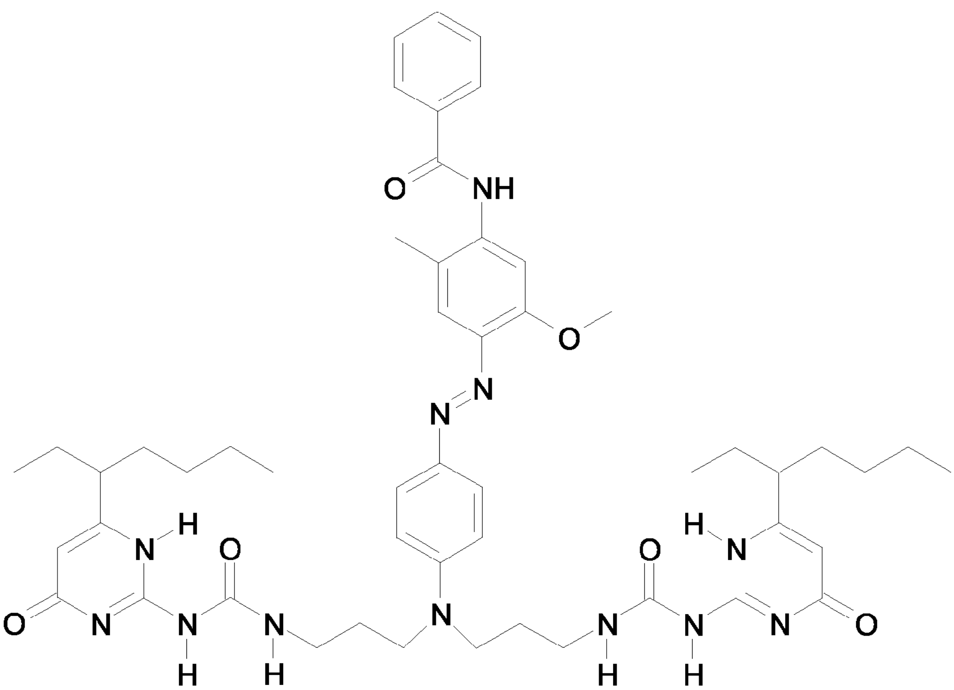
Dye 11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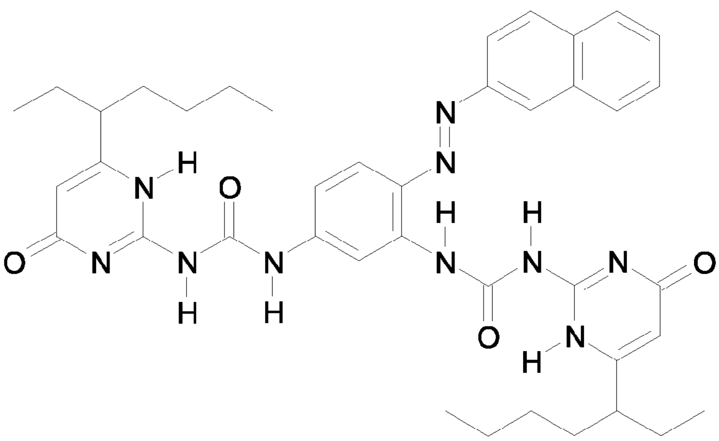
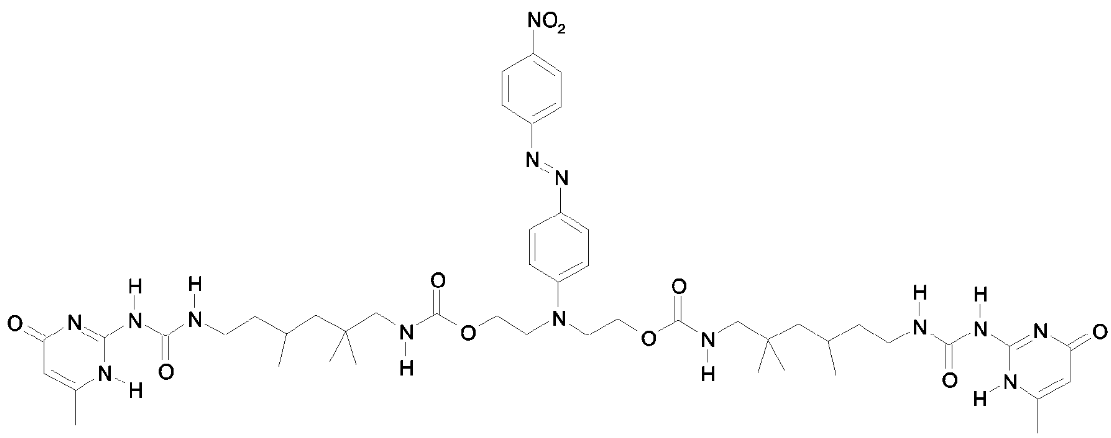
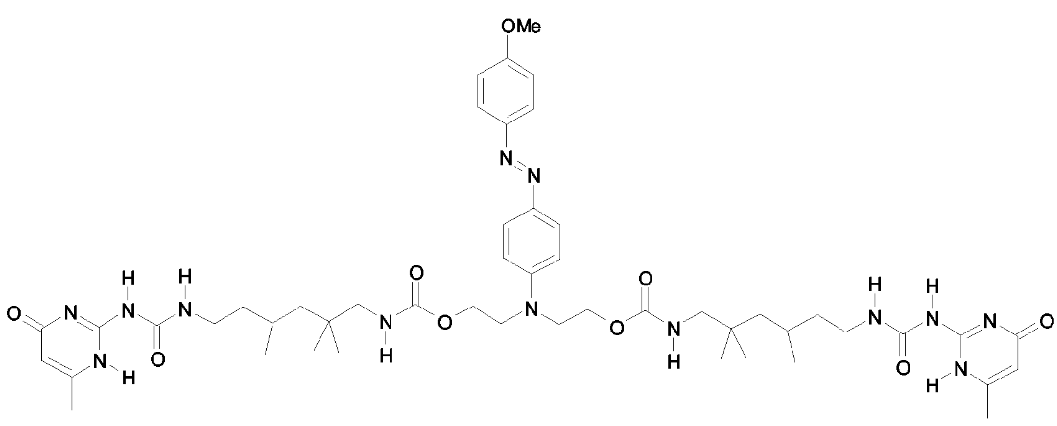
Dye 12



Dye 13



Dye 14



Dye 15

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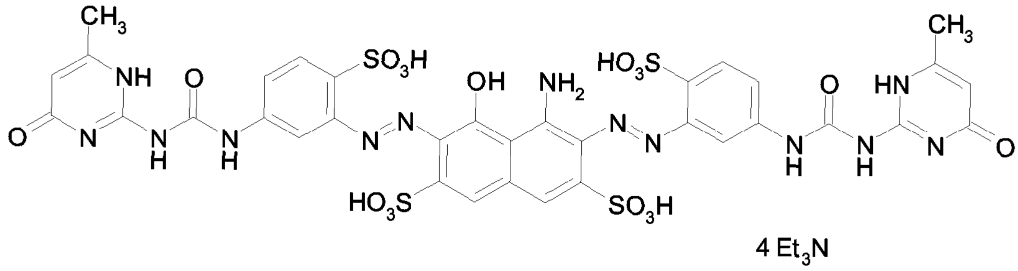
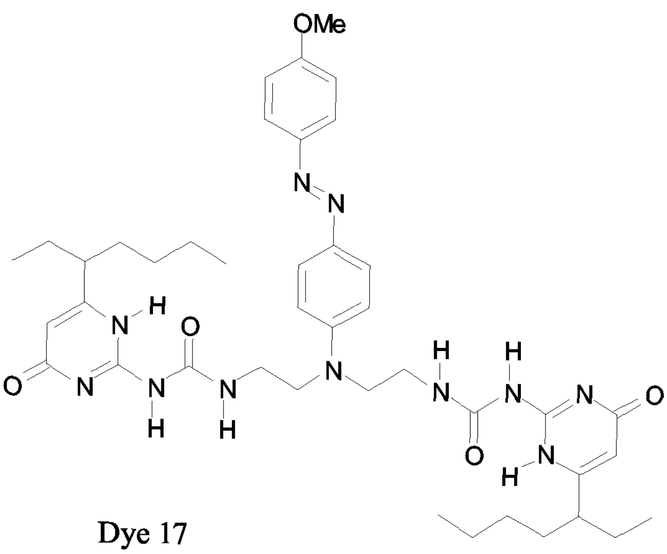
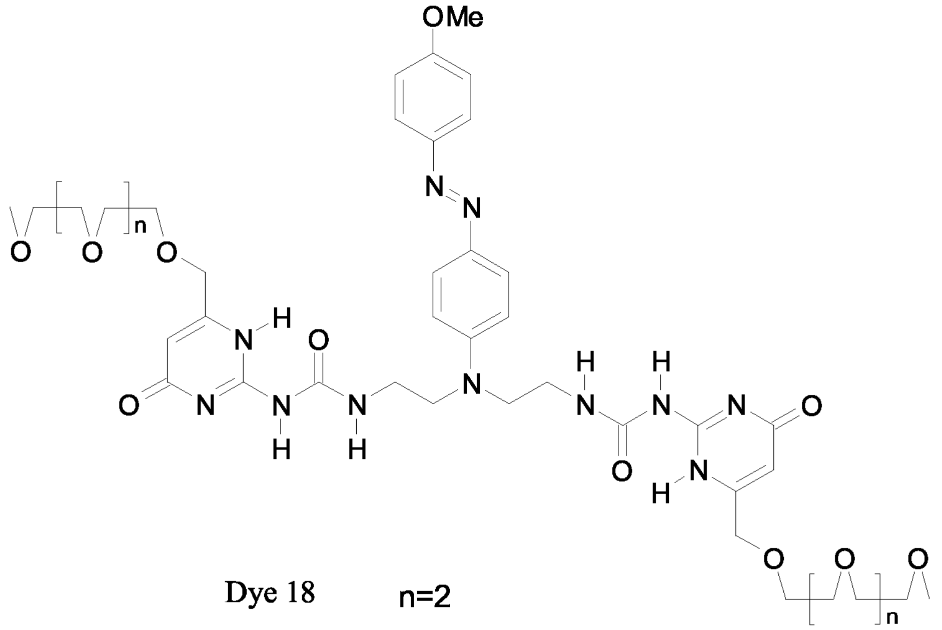


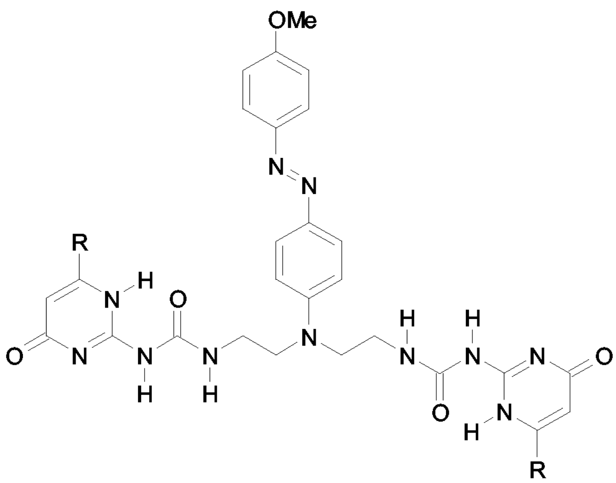
Dye 16

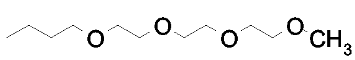


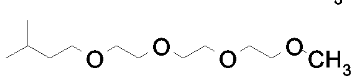
Dye 17

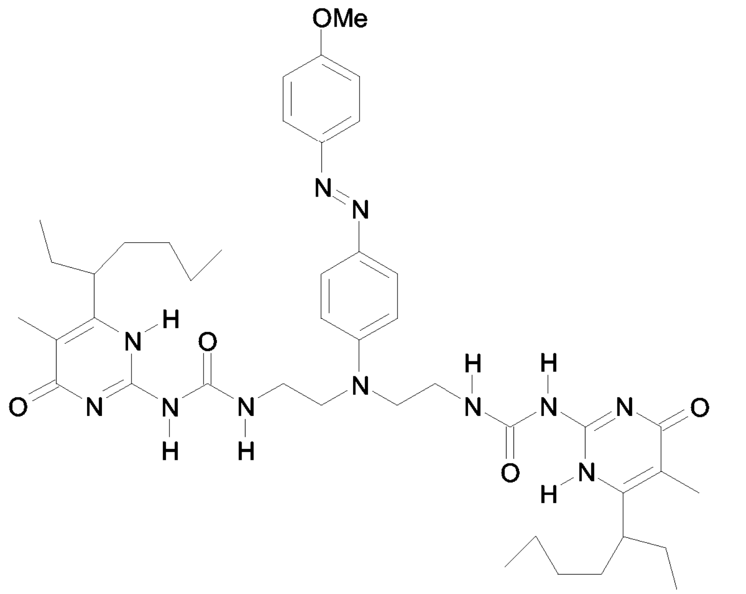


Dye 18 n=2

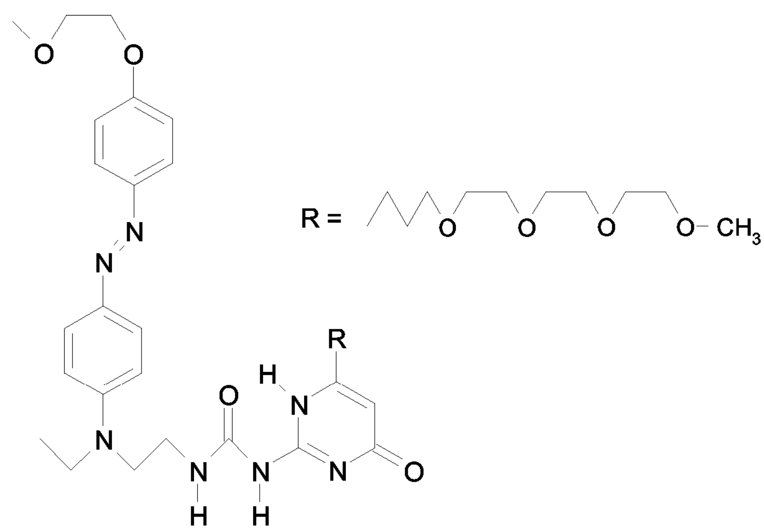


Dye 19 R = 

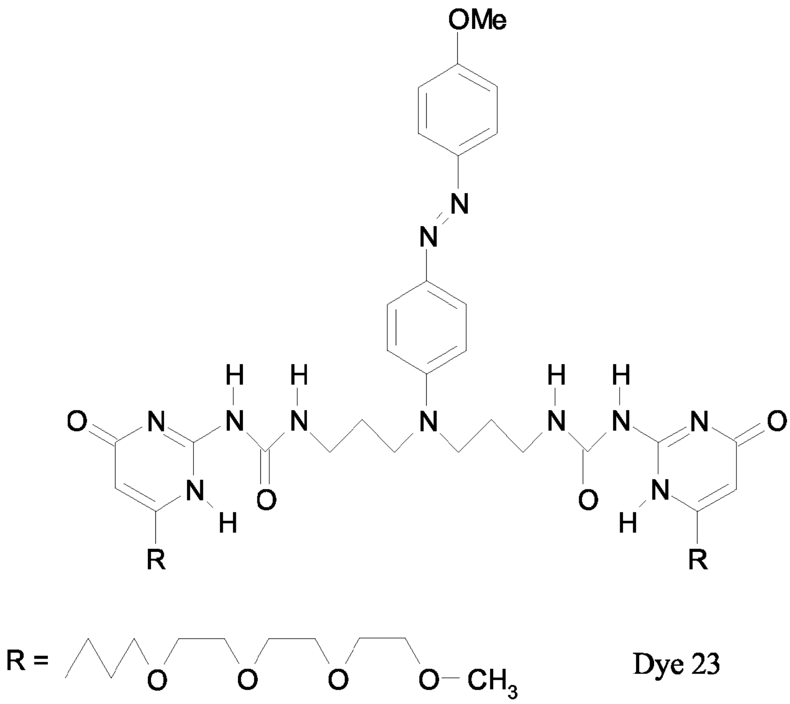
Dye 20 R = 



Dye 21



Dye 22



Dye 23

[0029] In a first embodiment of this invention, inks are formulated containing self-complementary dyes according to Formula (I). Self-assembly through the formation of intermolecular hydrogen bonds, is induced through evaporation of the ink vehicle. As long as the self-assembling dyes are dissolved in the ink no or partial self-assembly occurs because of the formation of hydrogen bonds with the ink vehicle. Once the ink vehicle (or one of the ink vehicles) is removed through, for example, evaporation, self-assembly of the dyes is induced resulting in supramolecular structures. In these assemblies the integrity of the individual component molecules normally remains largely intact: that is, the wave functions of the respective molecular components remain largely separate on complex formation. However, after the initial self-assembly process through hydrogen bonding has started, secondary interactions may occur such as π-stacking resulting in more rigid structures with different physical properties such as shifts in spectral absorption and molecular extinction coefficient, extra energy levels for thermal relaxation, etc.

[0030] In a second embodiment of this invention inks are formulated which contain at least one dye according to Formula (I) and further at least one other analogous dye $(CU')_{n'}(SAU')_{m'}$ whereby the SAU and SAU' residues are complementary so that the dyes are able to assemble with each other. Assembly through the formation of intermolecular hydrogen bonds is induced through evaporation of the ink vehicle. As long as the self-assembling dyes are dissolved in the ink no or partial self-assembly occurs because of the formation of hydrogen bonds with the ink vehicle. Once the ink vehicle (or one of the ink vehicles) is removed through, for example, evaporation, self-assembly of the dyes is induced resulting in supramolecular structures. The considerations about the integrity of the individual component molecules are the same as for the first embodiment.

[0031] In a third embodiment of this invention inks are formulated containing dyes according to Formula (I) and compounds according to formula (III):

$$(SAU'')_p(X)_q \qquad \text{Formula (III)}$$

wherein X is any linking group an Q is 0 or 1,

whereby the SAU and SAU" residues are complementary so that the dye(s) of Formula (I) and compounds according to formula (III) are able to assemble with each other. Assembly through the formation of intermolecular hydrogen bonds is induced through evaporation of the ink vehicle. As long as the assembling dyes are dissolved in the ink no or partial assembly occurs because of the formation of hydrogen bonds with the ink vehicle. Once the ink vehicle (or one of the ink vehicles) is removed through, for example, evaporation, assembly of the dyes is induced resulting in supramolecular structures. The considerations about the integrity of the individual component molecules are the same as for the first and second embodiment.

[0032] In a fourth embodiment of this invention the components of the self-assembly process are separated from each other. The dye(s) according to Formula (I) is (are) part of the ink while the analogous self-assembling dye(s) $(CU')_{n'}(SAU')_{m'}$ or the compounds according to formula (III) are incorporated into an ink receiving layer of an ink jet recording element.

[0033] So, apart from a process wherein ink compositions as defined above are used, the scope of the present invention further encompasses a process for the formation of an ink jet image comprising the step of image-wise jetting by means of an ink jet printing apparatus onto an ink jet recording element, comprising a support and at least one ink receiving layer, droplets of an ink composition comprising a liquid or solid vehicle and at least one dye according to formula (I).

[0034] The scope of the present invention further encompasses a process for the formation of an ink jet image comprising the step of image-wise jetting by means of an ink jet printing apparatus onto an ink jet recording element, comprising a support and at least one ink receiving layer, droplets of an ink composition comprising a liquid or solid vehicle and at least one dye according to formula (I).

[0035] The analogous self-assembling dye(s)$(CU')_{n'}(SAU')_{m'}$ or the compounds according to formula (III) can be present in the ink receiving layer of the ink jet recording element as single molecules or covalently linked to a polymer backbone such as gelatin, cellulose, polyvinyl alcohol, etc. Preferably the analogous self-assembling dye(s) $(CU')_{n'}$ $(SAU')_{m'}$ or the compounds according to formula (III) are present in the ink receiving layer as single molecules. The considerations about the mechanism of the assembly and about the integrity of the component molecules are the same as for the previous embodiments.

[0036] The dyes according to the present invention can be formulated in water based inks, in solvent and/or oil based inks, in UV-curable inks and in hot melt (phase change) inks. Typical ink compositions are described extensively in the existing patent literature and can be found for example in "Inkjet Technology and Product Development Strategies, Stephen F. Pond, Torrey Pines Research, 2000, Chapter 5: Ink Design" and references cited therein.

[0037] Preferred ink compositions are those comprising dyes according to the present invention in an aqueous medium and in a solvent and/or oil based medium.

[0038] The present dyes are useful as colorants for aqueous inks. The ink compositions of the present invention preferably contain from 0.5% to 40%, more preferably from 0.5% to 15%, and especially from 1% to 10%, by weight of the dye of Formula (I) based on the total weight of the ink. Although many ink compositions contain less than 5% by weight of colorant, it is desirable that the dye has a solubility of around 10% or more to allow the preparation of concentrates which may be used to prepare more dilute inks and to minimise the chance of precipitation of colorant if evaporation of the liquid medium occurs during use of the ink.

[0039] When the liquid medium is an aqueous medium it is preferably water or a mixture of water and one or more water-soluble organic solvents. The weight ratio of water to organic solvent(s) is preferably from 99:1 to 1:99, more preferably from 99:1 to 50:50 and especially from 95:5 to 80:20. The water-soluble organic solvent(s) is (are) preferably selected from C_{1-4} -alkanols such as methanol, ethanol, n-propanol, isopropanol, n-butanol, sec-butanol, tert-butanol; amides such as dimethylformamide or dimethylacetamide; ketones or ketone-alcohols such as acetone or diacetone alcohol; ethers such as tetrahydrofuran or dioxane; oligo- or poly-alkyleneglycols such as diethylene glycol, triethylene glycol, hexylene glycol, polyethylene glycol or polypropylene glycol; alkyleneglycols or thioglycols containing a C_2-C_6 alkylene group such as ethylene glycol, propylene glycol, butylene glycol, pentylene glycol or hexylene glycol and thiodiglycol; polyols such as glycerol or 1,2,6-hexanetriol; C_{1-4} -alkyl-ethers of polyhydric alcohols such as 2-methoxyethanol, 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)ethanol, 2-[2-(2-methoxyethoxy)ethoxy]ethanol, 2-[2-(2-ethoxyethoxy)-ethoxy]-ethanol, ethyleneglycolmonoallylether; heterocyclic amides, such as 2-pyrrolidone, N-methyl-2-pyrrolidone, N-ethyl-2-pyrrolidone and 1,3-dimethylimidazolidone; sulphoxides such as dimethyl sulphoxide and sulpholane or mixtures containing two or more of the aforementioned water-soluble organic solvents, for example thiodiglycol and a second glycol or diethylene glycol and 2-pyrrolidone. Preferred water-soluble organic solvents are 2-pyrrolidone; N-methyl-pyrrolidone; alkylene- and oligo-alkylene-glycols, such as ethyleneglycol, diethyleneglycol, triethyleneglycol; and lower alkyl ethers of polyhydric alcohols such as or 2-methoxy-2-ethoxy-2-ethoxyethanol; and polyethyleneglycols with a molecular weight of up to 500.

[0040] The present dyes are particularly useful as colorants for solvent and/or oil based inks. Solvent based ink compositions are used where fast drying times are required and particularly when printing onto hydrophobic substrates such as plastics, metal or glass. Where the liquid medium is solvent based the solvent is preferably selected from ketones, alkanols, aliphatic hydrocarbons, esters, ethers, amides or mixtures thereof. Where an aliphatic hydrocarbon is used as the solvent a polar solvent such as an alcohol, ester, ether or amide is preferably added. Preferred solvents include ketones, especially methyl ethyl ketone and alkanols especially ethanol and n-propanol.

[0041] Typical solvents for solvent based ink jet inks are methanol, ethanol, propanol, diacetone alcohol, methoxypropanol, glycol, methyl ethyl ketone, methyl isopropyl ketone, ethyl acetate, butyl acetate and methoxypropyl acetate, ethyl lactate and butyl lactate, monomethylethers from glycol, n.butylether from diethyleneglycol (Dowanol PM-series) and triethyleneglycol, tripropyleneglycolmonomethylether (TMP), dipropyleneglycolmonomethylether, and (di)methylnaphthalene. The less volatile solvents are more often used in oil based inks.

[0042] Solvent and/or oil based ink compositions of the present invention preferably contain from 0.5% to 40%, more preferably from 0.5% to 15%, and especially from 1% to 10%, by weight of the dye of Formula (1) based on the total weight of the ink. Although many ink compositions contain less than 5% by weight of colorant, it is desirable that the dye has a solubility of around 10% or more to allow the preparation of concentrates which may be used to prepare more dilute inks and to minimize the chance of precipitation of colorant if evaporation of the liquid medium occurs during use of the ink.

[0043] When the medium for an ink composition is a low melting point solid the melting point of the solid is preferably in the range from 60°C to 125°C. Suitable low melting point solids include long chain fatty acids or alcohols, preferably those with C_{18-24} chains, or sulphonamides. The dyes according to the present invention or mixtures of the dyes may be dissolved in the low melting point solid or may be finely dispersed in it.

[0044] For ink jet applications the viscosity of the final ink should be between 1-25 mPa.s at 20°C, preferably between 1-15 mPa.s at 20°C and most preferably between 1-10 mPa.s at 20°C for water and solvent-based inks, and between 1-25 mPa.s at 45°C, preferably between 2-18 mPa.s at 45°C and most preferably between 3-12 mPa.s at 45°C for oil-based inks.

[0045] The inks according to the present invention may contain further dyes other than the dyes according the present invention, for example to modify the colour or brightness of the ink. They may also contain stabilizing agents, such as UV-absorbers, singlet oxygen quenchers such as hindered amine light stabilizers, peroxide scavengers and other radical scavengers.

[0046] The ink jet recording element used in accordance comprises a support and optionally at least one ink receiving layer.

[0047] The support of the ink jet recording element can be chosen from the paper type and polymeric type support well-known from photographic technology. Paper types include plain paper, cast coated paper, polyethylene coated paper and polypropylene coated paper. Polymeric supports include cellulose acetate propionate or cellulose acetate butyrate, polyesters such as polyethylene terephthalate (PET) and polyethylene naphthalate, polyamides, polycarbonates, polyimides, polyolefins, poly(vinylacetals), polyethers and polysulfonamides. Other examples of useful high-quality polymeric supports for the present invention include opaque white polyesters and extrusion blends of polyethylene terephthalate and polypropylene. Polyester film supports, and especially polyethylene terephthalate, are preferred because of their excellent properties of dimensional stability. When the ink jet recording material is meant for outdoor use then typical useful supports include PET, wet strength paper, PVC, PVC with an adhesive backing, the polyethylene paper TYVEK, trade name of Du Pont Co., the porous polyethylene paper TESLIN, trade name of International Paper CO., canvas, polypropylene, and polycarbonate.

[0048] The ink receiving layer may contain the typical ingredients well-known in the art from numerous patent applications. Typical ingredients include binders, pigments, mordants, surfactants, spacing agents, whitening agents, UV-absorbers, hardeners, plasticizers, etc..

[0049] The scope of the present invention further encompasses an ink jet printing apparatus comprising an ink cartridge containing at least one dye according to formula (I), and optionally at least one analogous self-assembling dye $(s)(CU')_{n'}(SAU')_{m'}$, as extensively described above. The ink jet printing process can be performed according to any of the well-known techniques, such as the continuous printing method, the thermal jet method and the piezo method.

[0050] The present invention will now be illustrated by the following examples without however being limited thereto.

EXAMPLES

[0051] The Synthesis Examples 1 to 24 deal with the synthesis of the dyes used in accordance with the present invention, or of intermediates thereof. The evaluation of the dyes according to the present invention is described in the section 'Evaluation Examples'.

Measurement methods

[0052] UV data have been recorded in 1 cm sample holders with observed optical densities between 0.1 and 2.0. ε is given as $l.mol^{-1}.cm^{-1}$. Different Perkin Elmer UV-spectroscopes have been used. FT-IR spectra have been recorded on a Spectrum One Perkin Elmer ATR FT-IR spectroscope. NMR spectra have been recorded on a 300 MHz Varian spectroscope. MALDI-TOF MS data have been recorded on a Perceptive Voyager DE Pro spectrometer.

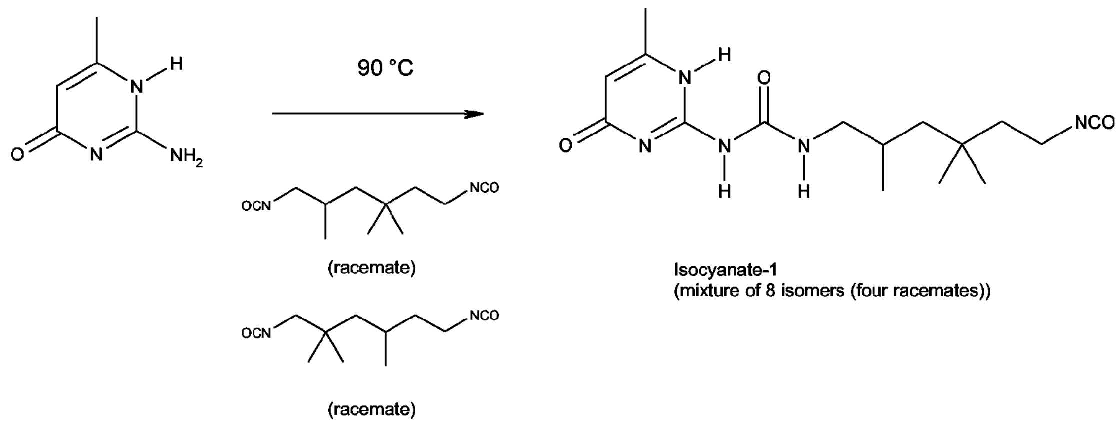
[0053] The density, i.e. optical density of the Evaluation Examples was measured using a MacBeth TR1224 densitometer.

SYNTHESIS EXAMPLES

[0054] The dyes according to the present invention can be prepared using synthetic methods known to those who are skilled in the art of organic synthesis.

Synthesis Example 1: synthesis of the Isocyanate-1.

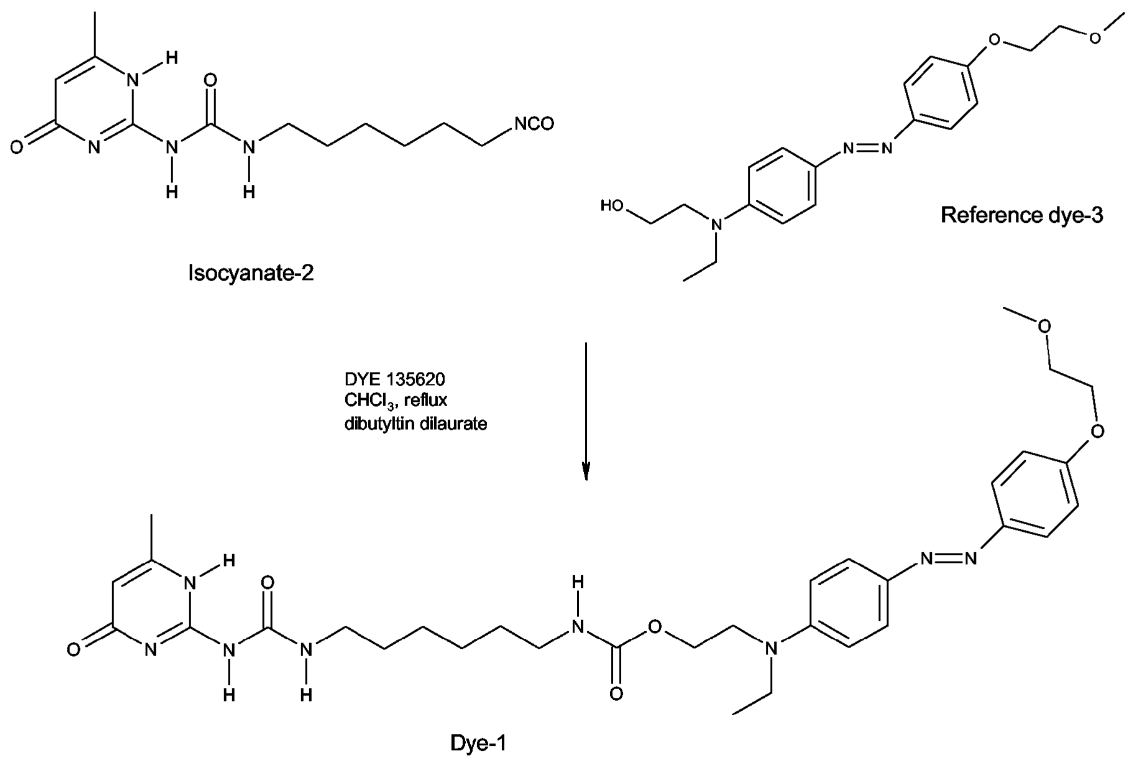
[0055]



3 mL of pyridine were added to a white suspension of the isocytosine (2 gram) and a mixture of 2,2,4-trimethyl-1,6-diisocyanate and 2,4,4-trimethyl-1,6-diisocyanate (24 gram). The mixture was heated for 21 hours at an oil bath temperature of 100°C under a slight argon flow. The reaction mixture was cooled to room temperature and pentane was added to induce precipitation of a white product. The suspension was filtered and the residue was washed several times with pentane to yield the isocyanate-1 as a white solid. Yield: 60%. 1H NMR (300 MHz, $CDCl_3$): δ = 0.95-1.05 (m, 9H), 1.1 (m, 1H), 1.3 (m, 1H), 1.6 (m, 2H), 1.8 (m, 1H), 2.2 (s, 3H), 3,0-3.4 (m, 4H), 5.8 (s, 1H) , 10.1 (s, 1H) , 11.7 (s, 1H) , 13.1 (s, 1H). IR : υ (cm-1) = 709, 744, 761, 798, 844, 946, 971, 1028, 1132, 1171, 1248, 1319, 1368, 1381, 1390, 1415, 1439, 1469, 1518, 1580, 1647, 1693, 2260, 2873 , 2933, 2956, 3143, 3196.

Synthesis Example 2: synthesis of Dye-1.

[0056]

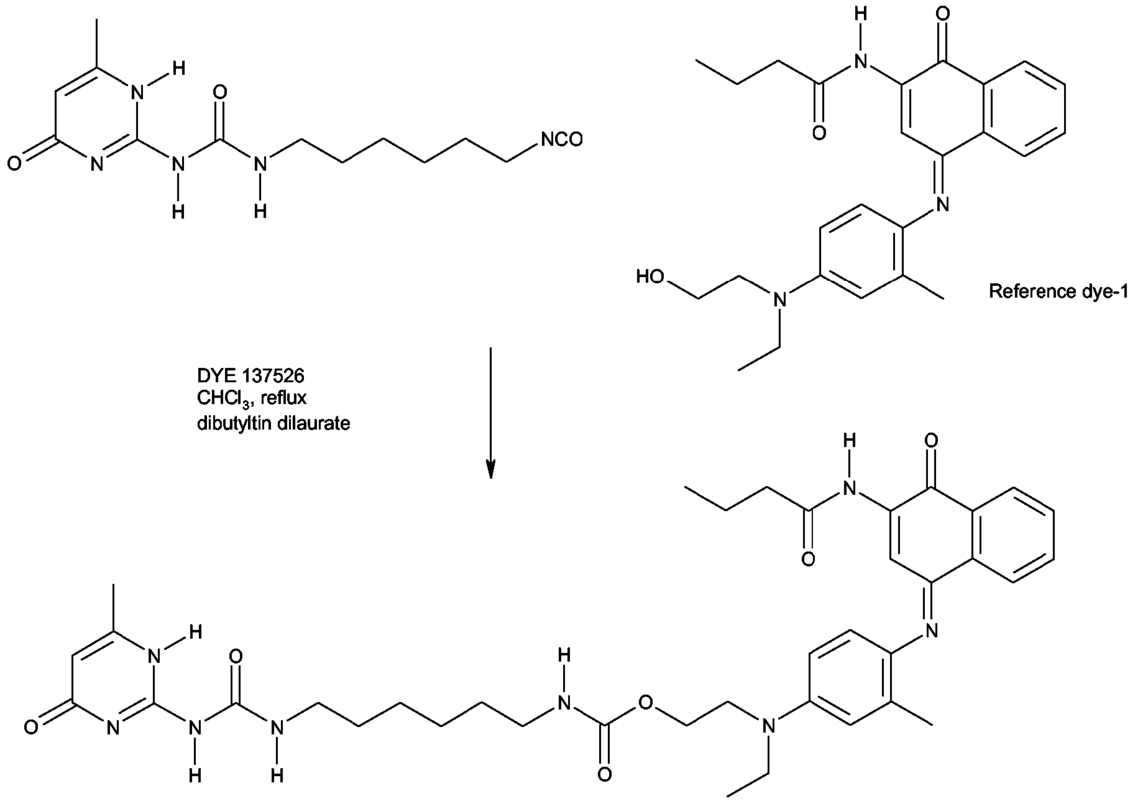


Reference dye-3 (17.4 gram) and the isocyanate-2 (prepared according to Example 1) (14.8 gram) were dissolved in 400 mL of dry chloroform. Several drops of the dibutyltin dilaurate catalyst were added and the reaction mixture was stirred under an argon atmosphere at an oil bath temperature of 80°C for 21 hours. The reaction mixture was cooled to room temperature and added dropwise to 700 mL of hexane. The precipitated fine yellow powder was filtered and purified through a second precipitation from chloroform into a mixture of hexane/chloroform (500 mL/200 mL). 29.1 gram (90%) of Dye-1 was obtained.

1H NMR (300 MHz, $CDCl_3$): δ = 1.1-1.7 (m, 11H), 2.1 (s, 3H), 3.0-3.2 (m, 4H), 3.4 (m, 5H), 3.6 (m, 2H), 3.7 (m, 2H), 4.1 (m, 2H), 4.3 (m, 2H), 5.15 and 5.2 (2s, 1H), 5.8 (s, 1H), 6.75 (d, 2H), 6.95 (d, 2H), 7.8 (d, 4H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). MALDI-TOF MS (FW=636.75), found m/z = 637.13. IR : υ (cm-1) = 666, 750, 823, 837, 923, 942, 1003, 1035, 1058, 1105, 1132, 1151, 1194, 1240, 1315, 1361, 1377, 1396, 1446, 1511, 1546, 1583, 1667, 1682, 1700, 2929, 3290. λmax = 409 nm; ε=26321 (CHCl3); λmax = 409 nm; ε=29000 (MeOH).

Synthesis Example 3: synthesis of Dye-2.

[0057]



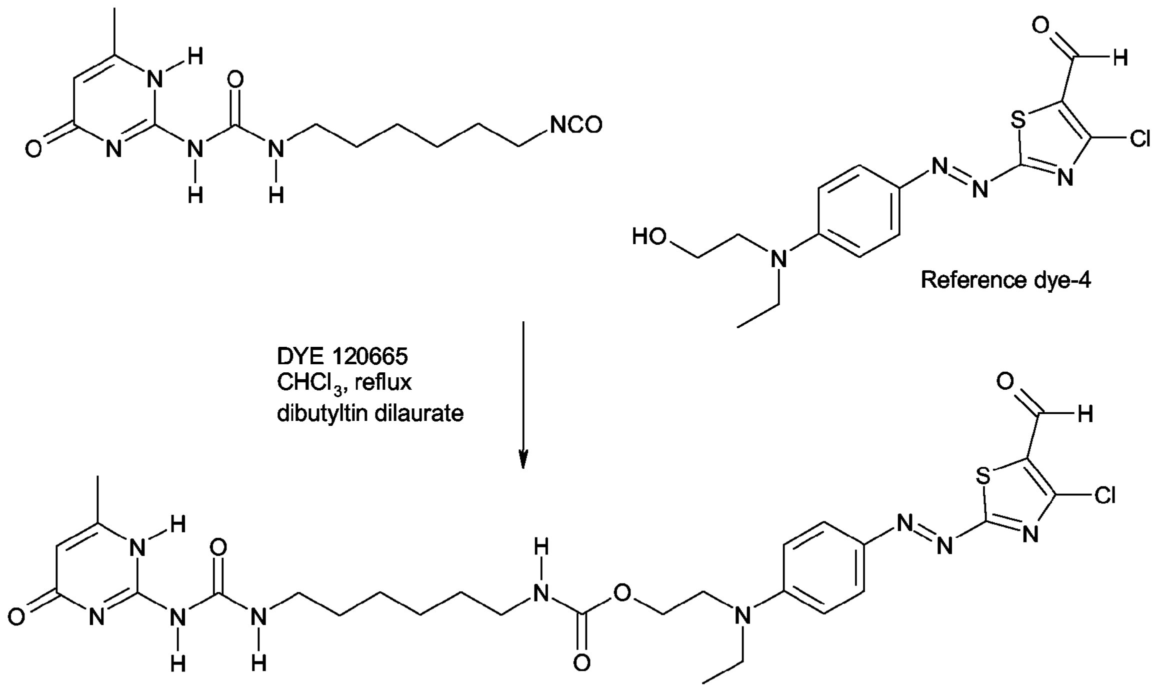
Dye-2

Reference dye-1 (709 mg) and the isocyanate-2 (470 mg) were dissolved in 50 mL of dry chloroform. Several drops of dibutyltin dilaurate (catalyst) were added. The reaction mixture was refluxed for 21 hours under argon, cooled to room temperature and the solvent was removed under reduced pressure. The compound was purified using column chromatography starting with pure chloroform as the eluent and gradually switching to 2% methanol/chloroform eluent. The collected product was precipitated in hexane (to remove the catalyst that is still present after chromatography). Yield: 90% of Dye-2.

1H NMR (300 MHz, $CDCl_3$): δ = 0.9 (t, 3H), 1.1-1.7 (m, 13H), 2.1 (s, 3H), 2.4 (s, 3H), 3.1 (m, 4H), 3.4 (m, 4H), 3.6 (s, 2H), 4.2 (m, 2H), 5.2-5.4 (2s, 1H), 5.8 (s, 1H), 6.6 (m, 1H), 6.7 (m, 2H), 7.5 (m, 1H), 7.6 (t, 1H), 8.1 (d, 1H), 8.4 (m, 2H), 9.3 (m, 1H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). MALDI-TOF MS (FW=712.84), found m/z = 714.24. IR: υ (cm-1) = 667, 753, 799, 842, 937, 988, 1029, 1072, 1101, 1139, 1193, 1250, 1318, 1353, 1393, 1446, 1470, 1501, 1534, 1578, 1606, 1660, 1698, 2859, 2929, 3288. λmax = 678 nm; ε=24288 (CHCl3); λmax = 681 nm; ε=23000 (MeOH).

Synthesis Example 4: synthesis of Dye-3.

[0058]



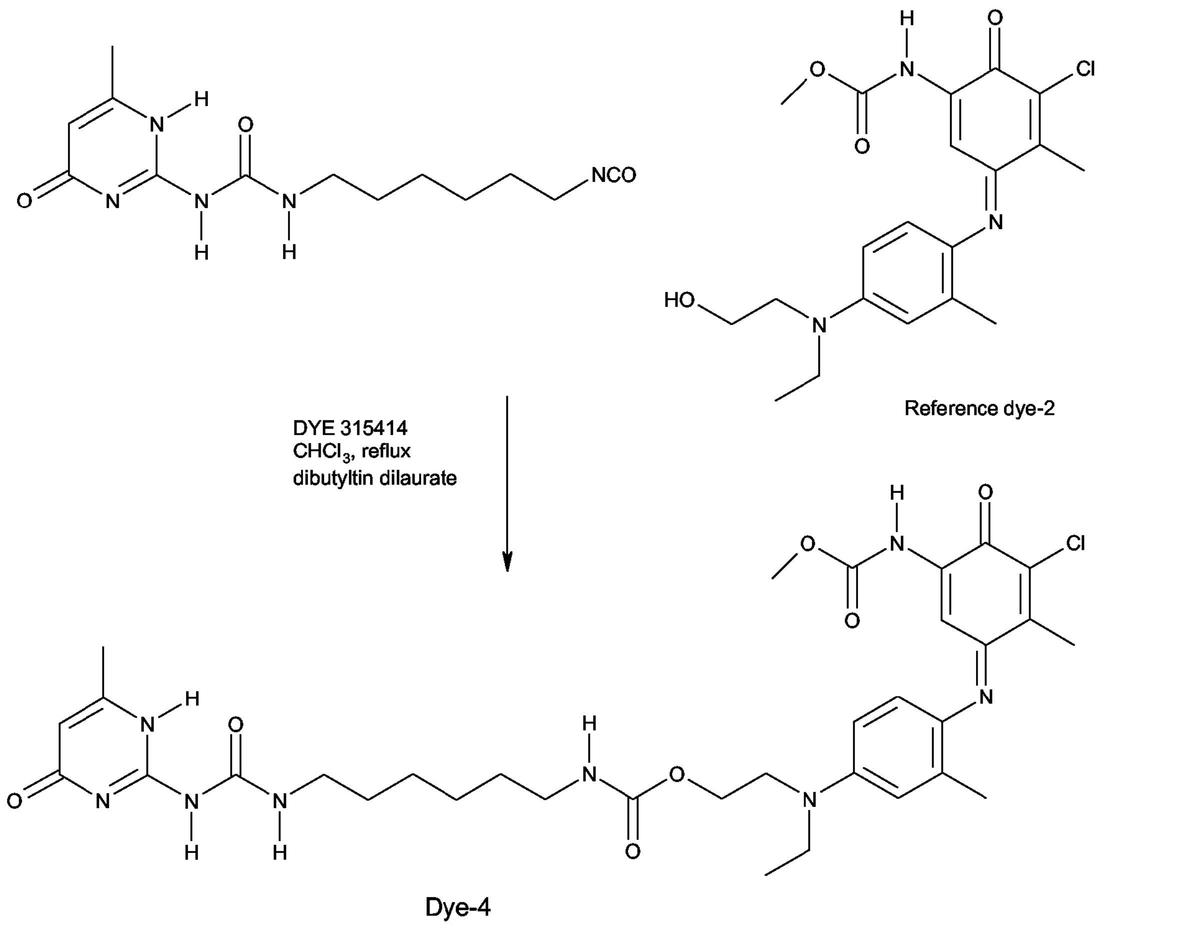
Dye-3

Reference dye-4 (706 mg) and the isocyanate-2 (579 mg) were dissolved in 50 mL of dry chloroform. Several drops of dibutyltin dilaurate (catalyst) were added, and the reaction mixture was boiled under an argon atmosphere for 21 hours. The reaction mixture was cooled to room temperature and the solvent was removed under reduced pressure. The compound was purified using column chromatography starting with pure chloroform as the eluent and gradually switching to 2% methanol in chloroform. The collected product was precipitated in hexane (to remove the catalyst) to yield 1.15 gram of Dye-3 (92%).

1H NMR (300 MHz, $CDCl_3$): δ = 1.1-1.6 (m, 11H), 2.2 (s, 3H), 3.2 (m, 4H), 3.6 (m, 2H), 3.7 (m, 2H), 4.3 (m, 2H), 5.2-5.4 (2s, 1H), 5.8 (s, 1H), 6.8 (m, 2H), 7.9 (d, 2H), 10.0 (s, 1H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). MALDI-TOF MS (FW=632.12), found m/z = 632.14. IR: υ (cm-1) = 653, 664, 684, 721, 799, 826, 880, 926, 997, 1072, 1101, 1215, 1242, 1309, 1327, 1372, 1411, 1445, 1482, 1519, 1581, 1595, 1658, 1697, 2856, 2928, 3214. λmax = 555 nm; ε=44000 (CHCl3); λmax = 547 nm; ε =38000 (MeOH).

Synthesis Example 5: synthesis of Dye-4.

[0059]

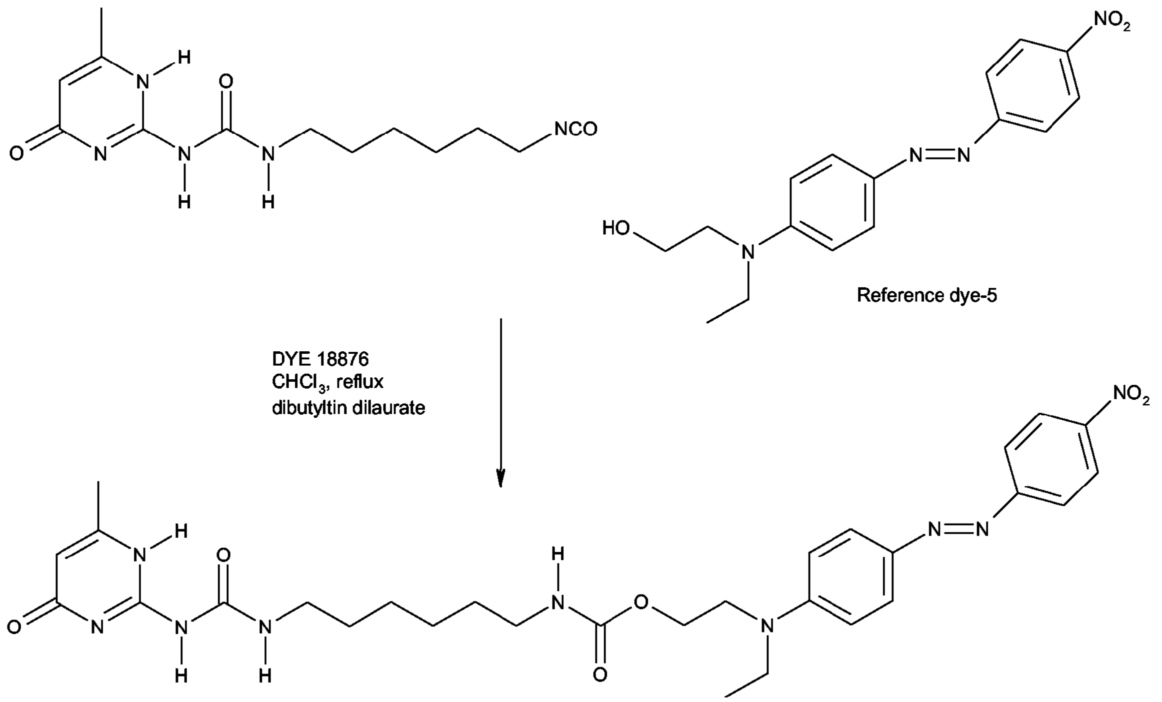


Reference Dye-2 (9.9 gram) and the isocyanate-2 (7.2 gram) were dissolved in 300 mL of dry chloroform. Several drops of dibutyltin dilaurate (catalyst) were added and the reaction mixture was refluxed for 21 hours under an argon atmosphere. The reaction mixture was cooled to room temperature and added dropwise to 700 mL of hexane. After a second precipitation Dye-4 is obtained as a blue powder: 16.1 gram (92%).

1H NMR (300 MHz, $CDCl_3$): δ = 1.2 (t, 3H), 1.3 (m, 4H), 1.4-1.6 (m, 4H), 2.2 (s, 3H), 2.3 (s, 3H), 2.5 (s, 3H), 3.0-3.2 (m, 4H), 3.4 (m, 2H), 3.5 (m, 2H), 3.7 (s, 3H), 4.2 (m, 2H), 5.1 and 5.3 (2s, 1H), 5.8 (s, 1H), 6.6 (m, 2H), 6.8 (d, 1H), 7.6 (s, 1H), 7.9 (s, 1H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). MALDI-TOF MS (FW=699.20), found m/z = 700.25. IR : υ (cm-1) = 664, 750, 784, 804, 843, 875, 917, 968, 1042, 1110, 1135, 1179, 1243, 1318, 1348, 1375, 1393, 1455, 1514, 1583, 1630, 1660, 1698, 1700, 2858, 2929, 3216, 3374. λmax = 653 nm; ε=26000 (CHCl3); λmax = 652 nm; ε=21000 (MeOH).

Synthesis Example 6: synthesis of Dye-5.

[0060]



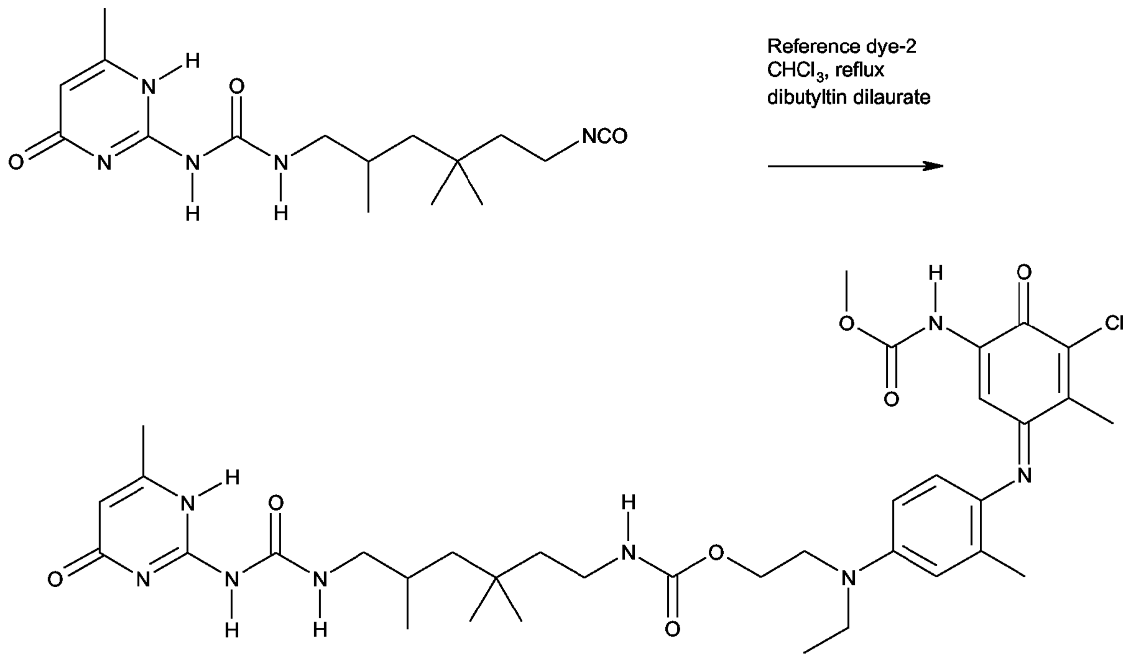
Dye-5

Reference dye-5 (1.0 gram) and the isocyanate-2 (1.0 gram) were mixed in 20 mL dry CHCl3 and 5 mL dry pyridine. Several drops of dibutyltin dilaurate (catalyst) were added and the reaction mixture was boiled and stirred under an argon atmosphere for several hours. The mixture was cooled. Evaporation and co-evaporation with toluene removed the solvent. Dye-5 was obtained as a red powder.

1H NMR (300 MHz, $CDCl_3$): δ = 3.1- 3.3 (m, 4H), 3.5 (m, 2H), 3.7 (m, 2H), 4.2 (m, 2H), 5.0-5.2 (2s, 1H), 5.8 (s, 1H), 6.8 (m, 2H), 7.9 (m, 4H), 8.3 (m, 2H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). MALDI-TOF MS (FW=607.7), found m/z = 608.2. IR : υ (cm-1) = 689, 741, 767, 798, 858, 943, 1041, 1105, 1133, 1194, 1251, 1311, 1338, 1384, 1446, 1512, 1590, 1662, 1698, 2857, 2932, 3230. λmax = 479 nm (CHCl3); λmax = 476 nm (MeOH).

Synthesis Example 7:synthesis of Dye-6.

[0061]



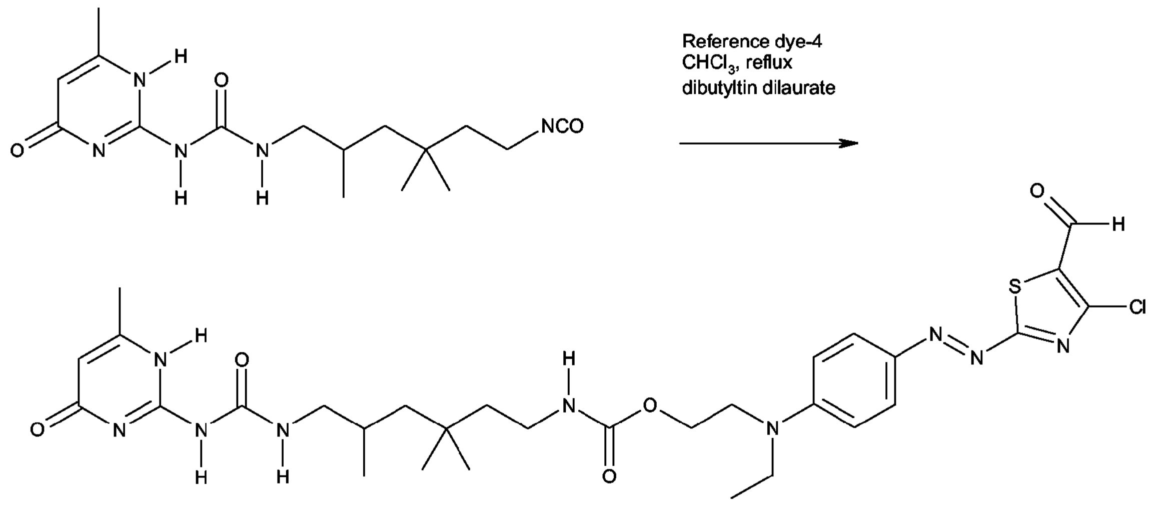
Dye-6

The isocyanate-1 (2.0 g; 5.96 mmol) and reference dye-2 (see example 5) (2.43 g; 5.99 mmol) were dissolved in 120 mL of dry chloroform. A few drops of dibutyltin dilaurate catalyst were added and the mixture was refluxed for 24 hours under an argon atmosphere. The reaction was monitored with TLC (2% MeOH/$CHCl_3$). Silica was added and the suspension was stirred for a few hours, followed by filtration. The filtrate was concentrated and the residue was dissolved in chloroform and precipitated in pentane to remove the catalyst; further purification was achieved with column chromatography (starting with pure chloroform as eluent and changing to 2% MeOH in chloroform). After chromatography, Dye-6 was precipitated from chloroform in pentane. Yield 3.28 gram (75%).

1H NMR (300 MHz, $CDCl_3$): δ = 0.9-1.0 (m, 10H), 1.2-1.4 (m, 4H), 1.5-1.7 (m, 3H), 2.2 (s, 3H), 2.3 (s, 3H) , 2.5 (s, 3H), 3.0 (m, 2H), 3.2 (m, 2H), 3.5 (m, 2H), 3.6 (m, 2H), 3.7 (s, 3H), 4.2 (m, 2H), 5.2-5.4 (2s, 1H), 5.8 (s, 1H), 6.6 (m, 2H), 6.75 (d, 1H), 7.7 (s, 1H), 7.9 (s, 1H), 10.1 (s, 1H), 11.7 (s, 1H), 13.1 (s, 1H). IR : υ (cm-1) = 666, 705, 745, 768, 784, 804, 842, 875, 917, 968, 1042, 1110, 1135, 1179, 1250, 1319, 1350, 1376, 1394, 1456, 1515, 1595, 1632, 1660, 1697, 1723, 2957, 3218, 3376. λmax = 655 nm; ε= 25000 ($CHCl_3$);λmax = 647 nm; ε= 21000 (MEK); λmax = 638 nm; ε= 24000 (EtOAc).

Synthesis Example 8:synthesis of Dye-7.

[0062]



Dye-7

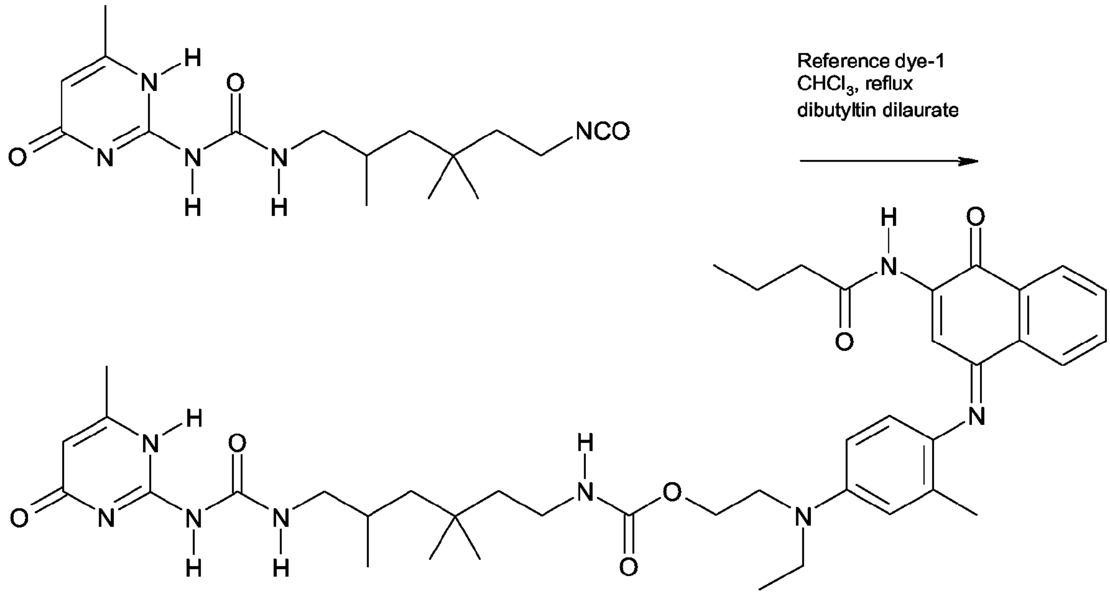
The isocyanate-1 (3.5 g; 10.4 mmol) and reference dye-4 (3.58 g; 10.6 mmol) were dissolved in 120 mL of dry chloroform. A few drops of dibutyltin dilaurate catalyst were added and the mixture was refluxed for 24 hours under argon. The reaction was followed with TLC (2% MeOH/$CHCl_3$). Silica was added and the suspension was stirred for a few hours, followed by filtration. The filtrate was concentrated under reduced pressure and the residue was dissolved in chloroform and precipitated in pentane to remove the catalyst; further purification was achieved with column chromatography (starting with pure chloroform as eluent and changing to 2% MeOH in chloroform; alternatively, EtOAc/hexane mixtures can be used). After chromatography, Dye-7 was precipitated from chloroform into pentane. Yield 4.2 gram (60%).

1H NMR (300 MHz, $CDCl_3$): δ 0.9 (m, 9H), 1.0-1.8 (8H), 2.2 (s, 3H), 2.8-3.0 (m, 4H), 3.5 (m, 2H), 3.7 (m, 2H), 4.3 (m, 2H), 5.2-5.4 (1H), 5.8 (s, 1H), 6.8 (m, 2H), 7.9 (m, 2H), 10.1 (m, 2H), 11.9 (bs, 1H), 13.1 (bs, 1H).

FT-IR: υ (cm-1) = 666, 684, 721, 761, 796, 826, 880, 925, 997, 1013, 1073, 1123, 1218, 1244, 1310, 1327, 1372, 1411, 1482, 1520, 1597, 1660, 1698, 2957. λmax = 553nm; ε=3700 (CHCl3);λmax = 561 nm; ε= 39000 (MEK); λmax = 553 nm; ε= 36000 (EtOAc).

Synthesis Example 9: synthesis of Dye-8.

[0063]



Dye-8

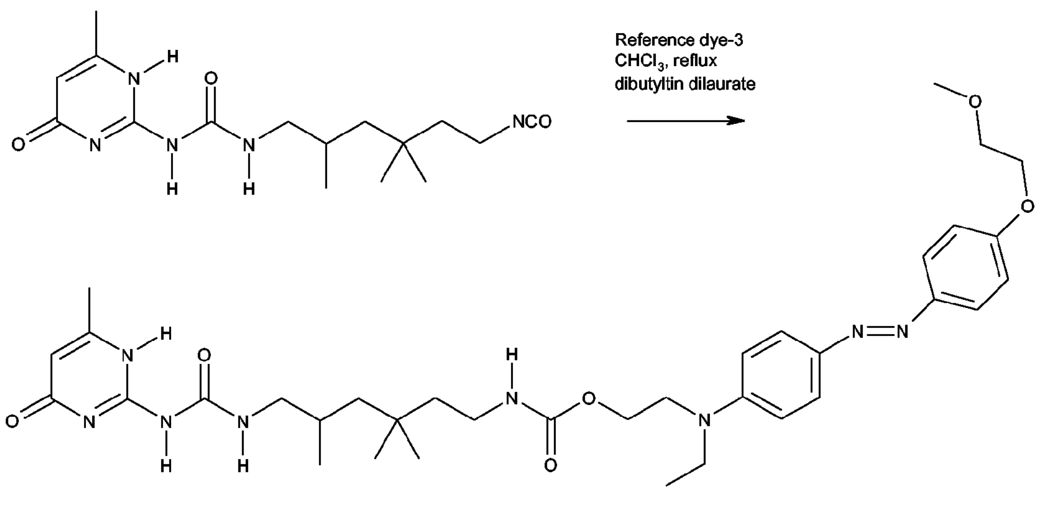
The isocyanate-1 (2.0 g; 5.96 mmol) and reference dye-1 (2.5 g; 5.96 mmol) were dissolved in 120 mL of dry chloroform. A few drops of dibutyltin dilaurate catalyst were added and the mixture was refluxed for 96 hours under argon. The reaction was followed with TLC (2% MeOH/$CHCl_3$). Silica was added and the suspension was stirred for a few hours, followed by filtration. The filtrate was concentrated under reduced pressure and the residue was dissolved in chloroform and precipitated in pentane to remove the catalyst; further purification was achieved with column chromatography (starting with pure chloroform as eluent and changing to 2% MeOH in chloroform; alternatively, EtOAc/hexane mixtures can be used). After chromatography, Dye-8 was precipitated from chloroform into pentane. Yield: 60%.

1H NMR (300 MHz, $CDCl_3$): δ 0.9-1.9 (22H), 2.2 (s, 3H), 2,4 (s, 3H), 3.0 (m, 2H), 3.2 (m, 2H), 3.4 (m, 4H), 3.6 (m, 2H), 4.3 (t, 2H), 5.2-5.4 (1H), 5.8 (s, 1H), 6.6 (d, 1H), 6.7 (m, 2H), 7.6 (t, 1H), 7.7 (t, 1H), 8.2 (d, 1H), 8.48 (s 1H), 8.55 (d, 1H), 9.3 (t, 1H), 10.1 (bs, 1H), 11.9 (bs, 1H), 13.1 (bs, 1H).

FT-IR: υ (cm-1) = 696, 754, 797, 841, 936, 1029, 1072, 1100, 1138, 1193, 1246, 1318, 1354, 1393, 1447, 1470, 1501, 1532, 1580, 1607, 1660, 1698, 2958. λmax = 684 nm; ε =25000 (CHCl3);λmax = 679 nm; ε = 22000 (MEK) ; λmax = 680 nm; ε = 22000 (EtOAc).

Synthesis Example 10:synthesis of Dye-9.

[0064]

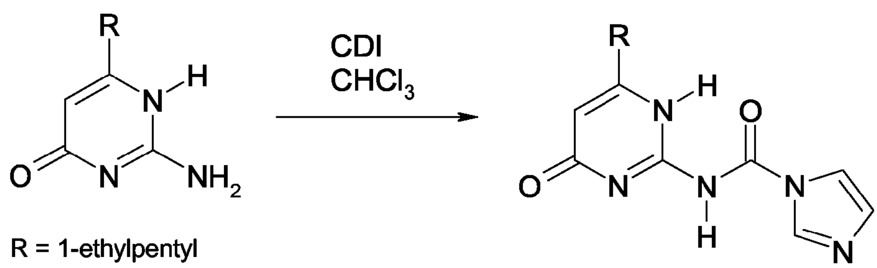


Dye-9

The isocyanate-1 (6.15 g; 18.3 mmol) and reference dye-3 (6.00 g; 17.5 mmol) were dissolved in 180 mL of dry chloroform. A few drops of dibutyltin dilaurate catalyst were added and the mixture was refluxed for 24 hours under argon. The reaction was followed with TLC (2% MeOH/$CHCl_3$) and IR. The reaction mixture was evaporated under reduced pressure and the residue was precipitated from chloroform into pentane to remove the catalyst. The compound was then purified with column chromatography (starting with 1/1 EtOAc/hexane as eluent and changing gradually to 3/1 EtOAc/hexane; the product was collected by eluting with 4% MeOH in chloroform). After chromatography, dye-9 was precipitated from chloroform into pentane.
1H NMR (300 MHz, $CDCl_3$): δ 0.9 (m, 9H), 1.0-1.8 (8H), 2.2 (s, 3H), 3.0 (m, 2H), 3.3 (m, 2H), 3.5 (m, 5H), 3.6 (m, 2H), 3.8 (m, 2H), 4.2-4.4 (m, 4H), 5.0-5.4 (three m, 1H), 5.8 (s, 1H), 6.8 (m, 2H), 7.0 (d, 2H), 7.8 (m, 4H), 10.1 (m, 1H), 11.9 (bs, 1H), 13.1 (bs, 1H).
FT-IR: υ (cm-1) = 664, 731, 775, 821, 836, 924, 1033, 1060, 1133, 1149, 1196, 1242, 1316, 1355, 1396, 1447, 1511, 1581, 1594, 1660, 1697, 2956, 3216. λmax = 409 nm; ε =29112($CHCl_3$).

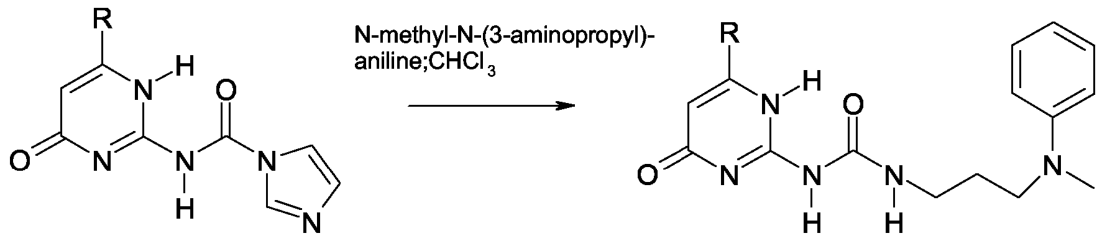
Synthesis Example 11: synthesis of Dye-10.

[0065]



CDI activation of 6-(1-ethylpentyl)isocytosine.

[0066] 6-(1-Ethylpentyl)-isocytosine (3.0 gram, 14.4 mmol) and carbonyldiimidazole (CDI; 3.24 gram, 20 mmol) were stirred at room temperature in 40 mL $CHCl_3$ for two hours, during which the mixture was kept under an argon atmosphere. The solution was washed with an aqueous NaCl solution, dried with $MgSO_4$ and concentrated to give a quantitative yield of CDI-activated product. NMR analyses showed signals at the expected resonances and no traces of excess CDI were discerned. (The isocytosine starting product had been prepared by a standard coupling procedure of its β-keto ester precursor and guanidine carbonate). 1H NMR ($CDCl_3$), λ = 12.9 (2H, bs), 8.6 (1H, s), 7.5 (1H, s), 6.9 (1H, s), 5.7 (1H, s), 2.4 (1H, m), 1.6 (4H, m), 1.2 (4H, m), 0.95-0.7 (6H, m).

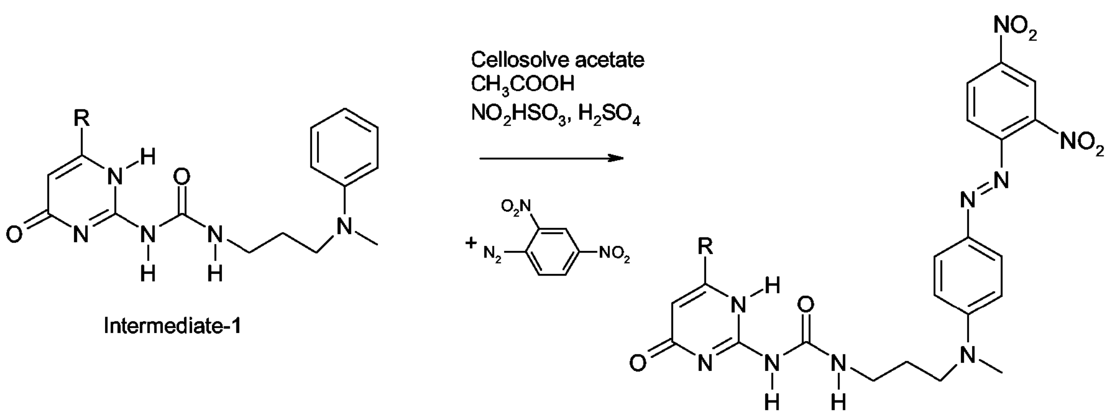


R = 1-ethylpentyl

Intermediate-1

Synthesis of Intermediate-1.

[0067] The CDI-activated product of (1-ethylpentyl)-isocytosine (4.3 gram, 14.4 mmol) was stirred overnight at room temperature in $CHCl_3$ together with N-methyl-N-(3-aminopropyl)-aniline (2,45 gram, 15 mmol). The solution was subsequently washed with a HCl solution and a NaHCO3 solution, and thereafter dried and concentrated. Column chromatography over silica with hexane/EtOAc 1/1 gave 4.8 gram of Intermediate-1 (85%). The oil solidified on standing. 1H NMR ($CDCl_3$), δ = 13.2 (1H, s), 12.0 (1H, s), 10.3 (1H, s), 7.2 and 6.7 (5H), 5.8 (1H, s), 3.5-3.3 (4H, m), 3.0 (3H, s), 2.3 (1H, m), 1.9 (2H, m), 1.8-1.5 (4H, m), 1.3 (4H, m), 0.95-0.8 (6H, m).



Intermediate-1

Dye-10

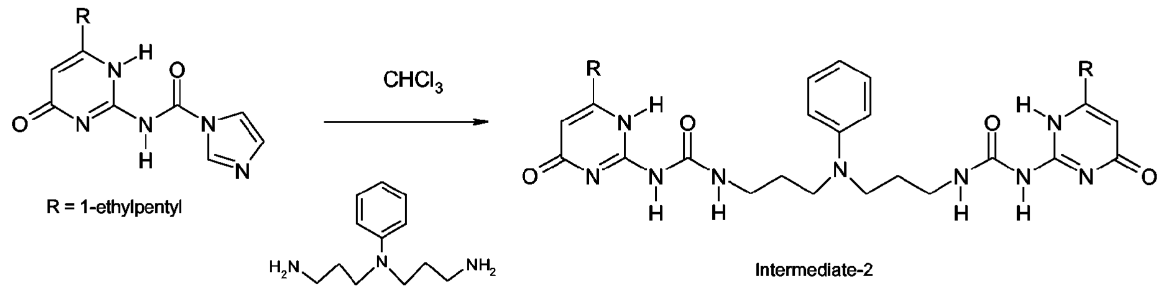
Synthesis of Dye-10.

[0068] 2,4-Dinitroaniline (0.6 gram, 3.3 mmol) was suspended in 4.5 mL of acetic acid and 0.6 mL of H_2SO_4. A 40% solution of nitrosyl sulfuric acid (NO_2HSO_3, 0.9 gram, 2.8 mmol) in H_2SO_4 was added to this mixture, while remaining the mixture at 15 °C. Stirring was continued for 30 minutes. The resulting yellow solution was added dropwise to a cooled solution of Intermediate-1 (0.5 gram, 1.26 mmol) in 4 mL of cellosolve acetate. The mixture turned red and was stirred overnight, while the temperature of the mixture was allowed to rise from 5 °C to room temperature. The clear mixture was poured on crushed ice to yield a purple-reddish solid that was filtered and washed with water. The product was dissolved in $CHCl_3$,washed twice with a $NaHCO_3$ solution, and once with a saturated NaCl solution. After drying over $MgSO_4$, and concentration, the product was dissolved in $CHCl_3$ and a small amount of acetic acid, and this solution was added dropwise to warm ethanol, yielding pure Dye-10 (0.37 gram, 50%).
1H NMR ($CDCl_3$), δ = 13.1 (1H, s), 12.0 (1H, s), 10.4 (1H, s), 8.7 (1H, s), 8.4 (1H, d), 7.9 (3H, m), 6.8 (2H, d), 5.8 (1H,

s), 3.6 (2H, m), 3.4 (2H, m), 3.2 (3H, s), 2.3 (1H, m), 2.0 (2H, m), 1.7-1.5 (4H, m), 1.3 (4H, m), 0.9 (6H, m).

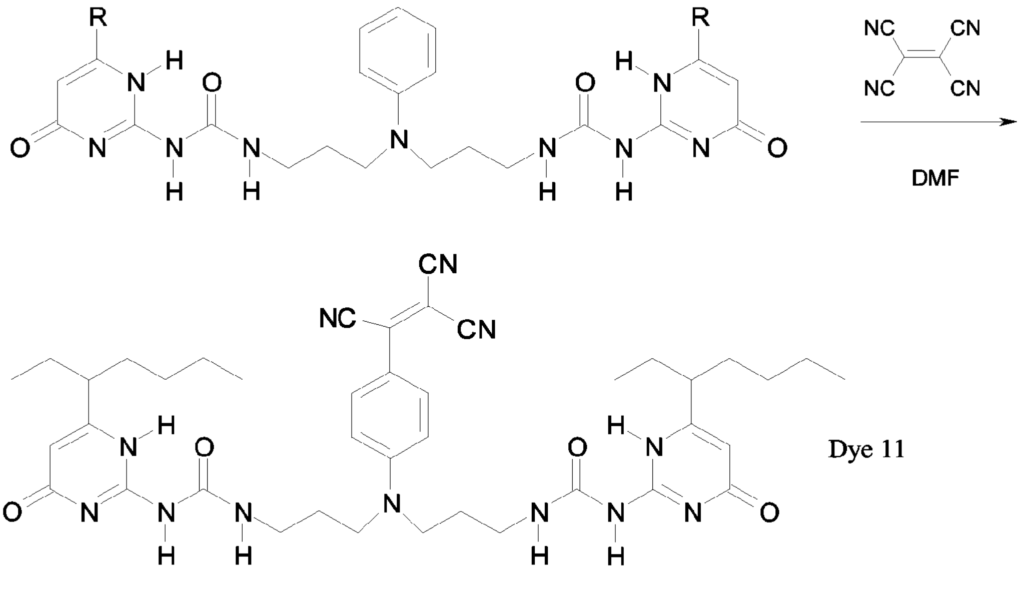
Synthesis Example 12: synthesis of Dye-11.

[0069]



Synthesis of Intermediate-2.

[0070] The CDI-activated product of (1-ethylpentyl)-isocytosine (2.6 gram, 8.5 mmol, 2.2 equivalents) was stirred overnight at room temperature in $CHCl_3$ together with N-(bis-3-aminopropyl)-aniline (0.8 gram, 3.85 mmol). The solution was subsequently washed with a HCl solution and a NaHCO3 solution, and thereafter dried and concentrated. The product was dissolved in $CHCl_3$ and a small amount of acetic acid and was precipitated in ethanol. The suspension was heated until a clear solution was obtained. After cooling, pure Intermediate-2 was isolated as a white precipitate. (The diamine had been prepared by cyanoethylation of aniline, subsequent hydrogenation and purification by distillation under reduced pressure).
1H NMR ($CDCl_3$), δ = 13.1 (2H, s), 12.0 (2H, s), 10.3 (2H, s), 7.4-7.0 and 6.8-6.5 (5H), 5.8 (2H, s), 3.5-3.3 (8H, m), 2.3 (2H, m), 2.0 (4H, m), 1.6 (8H, m), 1.3 (8H, m), 0.95-0.7 (12H, m).



Dye 11

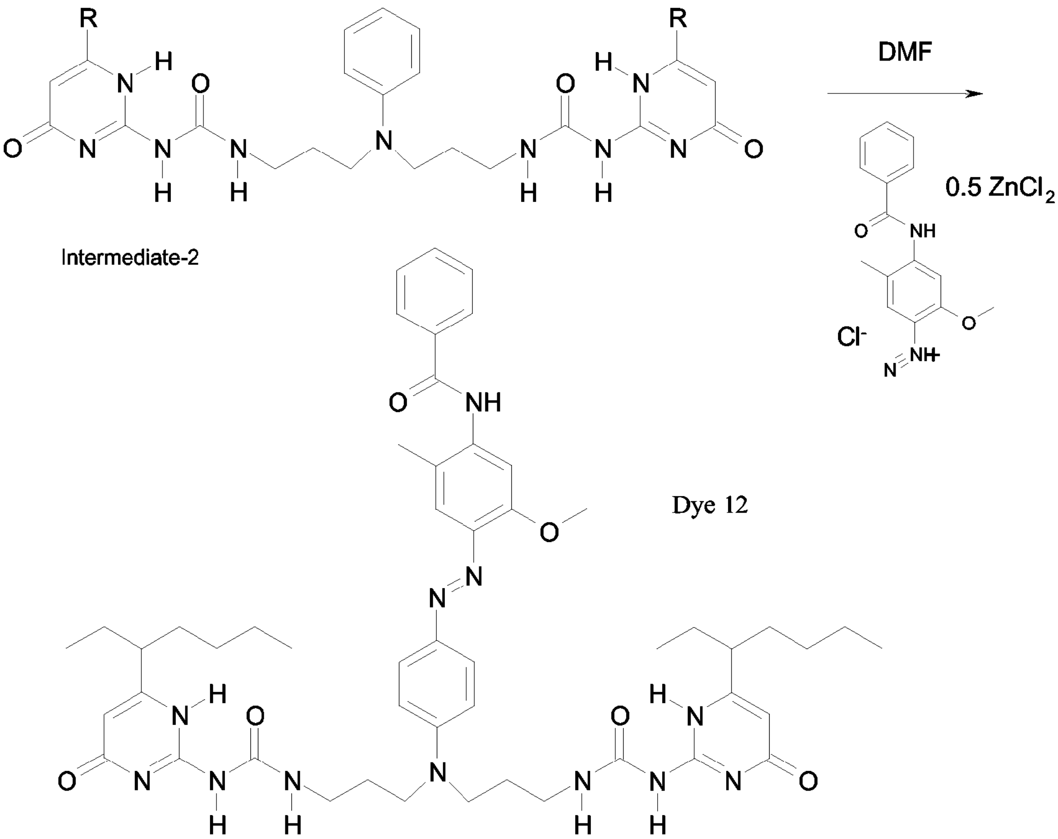
Synthesis of Dye-11.

[0071] Tetracyanoethylene (0.104 gram, 0.81 mmol) in 1.5 mL DMF was added dropwise to a heated (65 °C) suspension of Intermediate-2 (0.5 gram, 0.74 mmol) in 1.5 mL DMF. During addition a purple-reddish Colour developed (the reaction mixture was flushed with nitrogen, and the nitrogen was led through a NaOH/NaOCl trap to remove HCN). After the addition was complete, the mixture was stirred for 1.5 hours at 70 °C. Addition of 6 mL ethanol, further stirring

for an hour, cooling to room temperature and addition of some water resulted in a suspension that was filtered and washed with water and ethanol.
After drying the structure of Dye-11 was confirmed by MALDI-TOF MS ([M+]=779, [M+Na+]=802, [M+K+]=818).

Synthesis Example 13: synthesis of Dye-12.

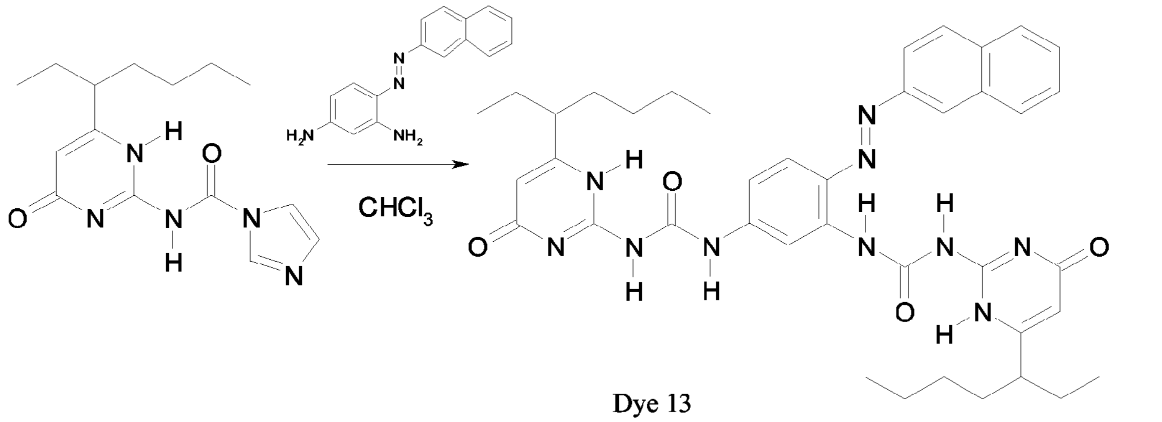
[0072]



[0073] Intermediate-2 (0.25 gram, 0.37 mmol) was stirred in 5 mL DMF at 65 °C together with the commercial diazonium salt (fast violet B salt, 0.283 gram, 0.76 mmol). The mixture became homogeneous and dark and was stirred at the given temperature for 1.5 hours. After cooling, $CHCl_3$ was added and the mixture was washed with acidic water and with a $NaHCO_3$ solution. After drying and precipitation the precipitate was purified using column chromatography. MALDI-TOF MS analysis as well as NMR analysis confirmed the structure of Dye-12. ([M+H+]=946, [M+Na+]=968).

Synthesis Example 14: synthesis of Dye-13.

[0074]



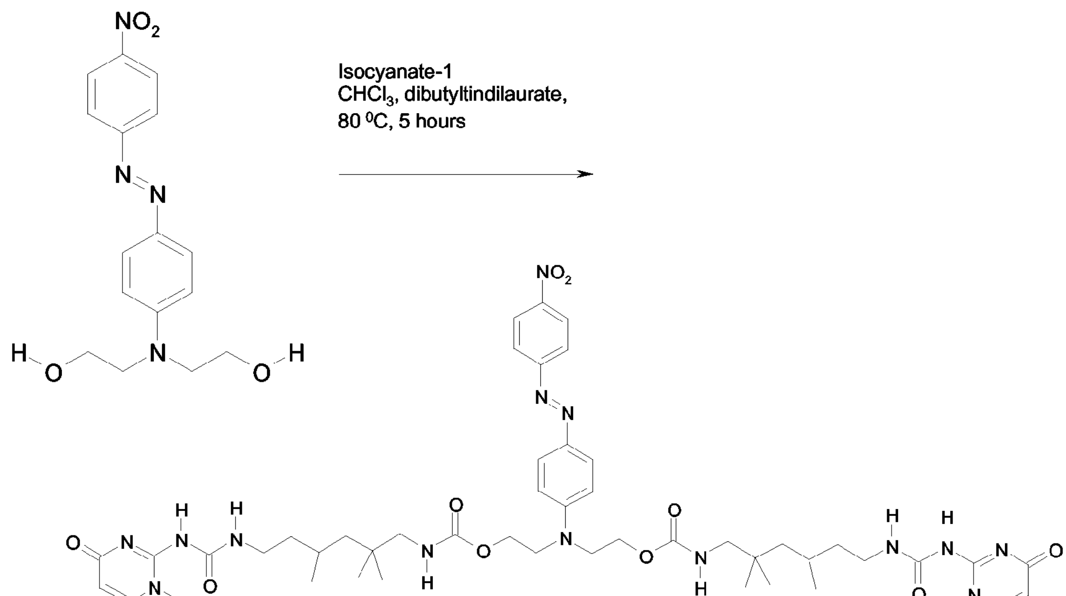
Dye 13

[0075] The activated 6-(1-ethylpentyl)isocytosine (2.8 gram; 9.3 mmol) was dissolved in 50 mL dry $CHCl_3$ together with Solvent Brown 1 (Fat Brown RR;C.I.11285)(1.06 gram, 4.0 mmol), and the mixture was heated in an oil bath of 80 °C for about 20 hours. Purification by column chromatography (silica; $CHCl_3$/MeOH, 98/2), and then by precipitation into acetone afforded Dye-13 as an orange solid.

1H NMR ($CDCl_3$, TFA-D1), δ = 12.0 (6H, bs), 8.9 (1H, d), 8.4 (1H, bs), 8.0 (4H, m), 7.6 (4H, m), 6.3 (1H, s), 6.2 (1H, s), 2.6 (2H, m), 1.7 (8H, m), 1.4 (8H, m), 1.0 (12H, m). λmax = 408 nm; ε =19868 ($CHCl_3$). MALDI-TOF MS analysis, [M+H+] = 734, [M+Na+] = 756, [M+K+] = 772. λmax = 408 nm; ε =20000 ($CHCl_3$).

Synthesis Example 15: synthesis of Dye-14.

[0076]



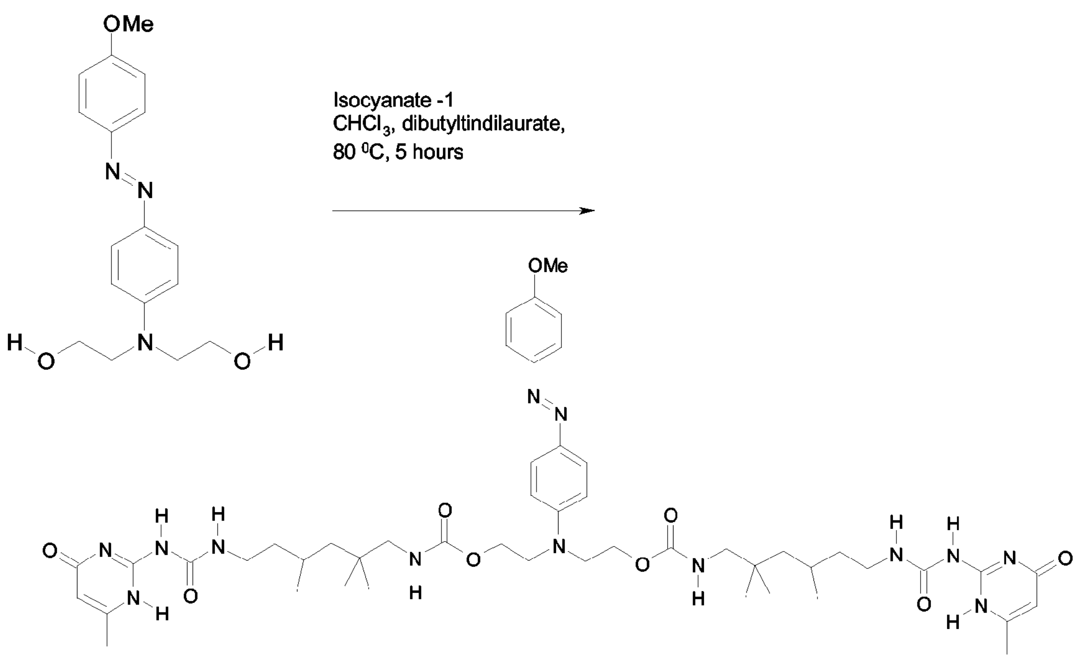
Dye 14

[0077] The starting diol (0.5 gram), Isocyanate-1 (1.11 gram) and a drop of dibutyltin dilaurate catalyst were mixed and heated in 100 mL of dry chloroform. After 24 hours of reflux, all isocyanate was consumed (FTIR analysis). The

red product Dye-14 was isolated using column chromatography (silica, $CHCl_3$/MeOH, 98/2).
1H NMR ($CDCl_3$), δ = 13.1 (2H, bs), 11.8 (2H, bs), 10.1 (2H, bs), 8.3 (2H, m), 7.9 (4H, m), 6.8 (2H, m), 5.8 (2H, s), 5.8-5.2 (2H), 4.2 (4H, m), 3.7 (4H, m), 3.3-2.8 (8H), 2.2 (6H, s), 1.8-1.2 (8H, m), 1.0 (20H, m).λmax = 464 nm; ε =28465 ($CHCl_3$).
MALDI-TOF MS analysis, [M+H+] = 1001, [M+Na+] = 1023.
λmax = 464 nm; ε =28000 ($CHCl_3$).

Synthesis Example 16: synthesis of Dye-15.

[0078]

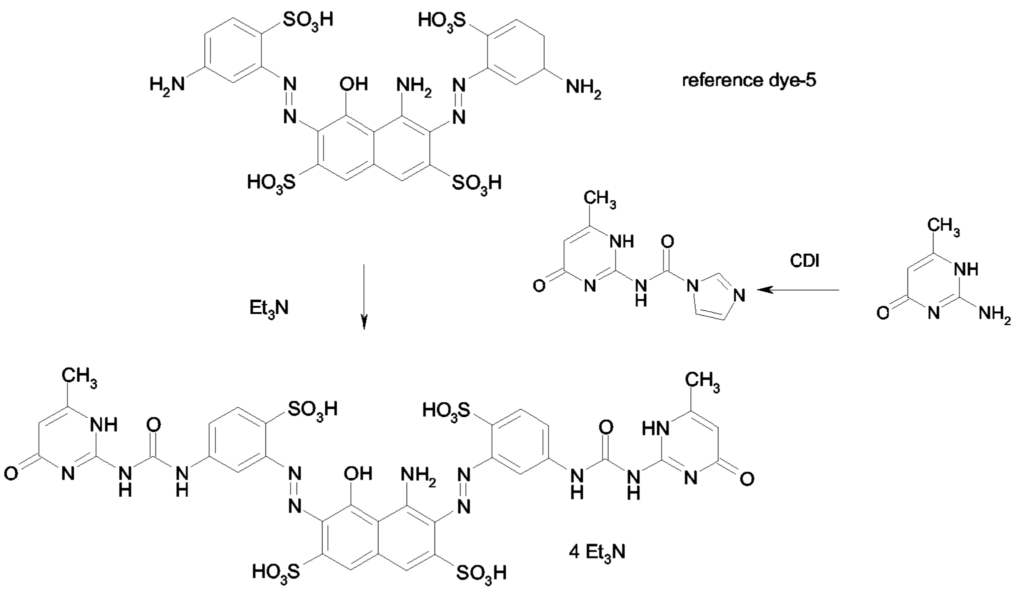


Dye 15

[0079] The starting diol (1 gram), Isocyanate-1 (2.3 gram) and a drop of dibutyltin dilaurate catalyst were mixed and heated in 100 mL of dry chloroform. After 40 hours of reflux isocyanate-1 was completely consumed (FTIR analysis). After column chromatography (silica, $CHCl_3$/MeOH, 98/2) Dye-15 (1.25 gram) was isolated as a yellow powder.
1H NMR ($CDCl_3$), δ = 13.1 (2H, bs), 11.8 (2H, bs), 10.1 (2H, bs), 7.8 (4H, m), 6.9 (2H, m), 6.7 (2H, m), 5.8 (2H, s), 5.6-5.2 (2H), 4.2 (4H, m), 3.8 (3H, s), 3.6 (4H), 3.3-2.8 (8H), 2.2 (6H, s), 1.8-1.2 (8H, m), 1.0 (20H, m).λmax = 405 nm; ε =31920 ($CHCl_3$).
MALDI-TOF MS analysis, [M+H+] = 985, [M+Na+] = 1009.
λmax = 405 nm; ε =32000 ($CHCl_3$).

Synthesis Example 17: synthesis of Dye-16.

[0080]



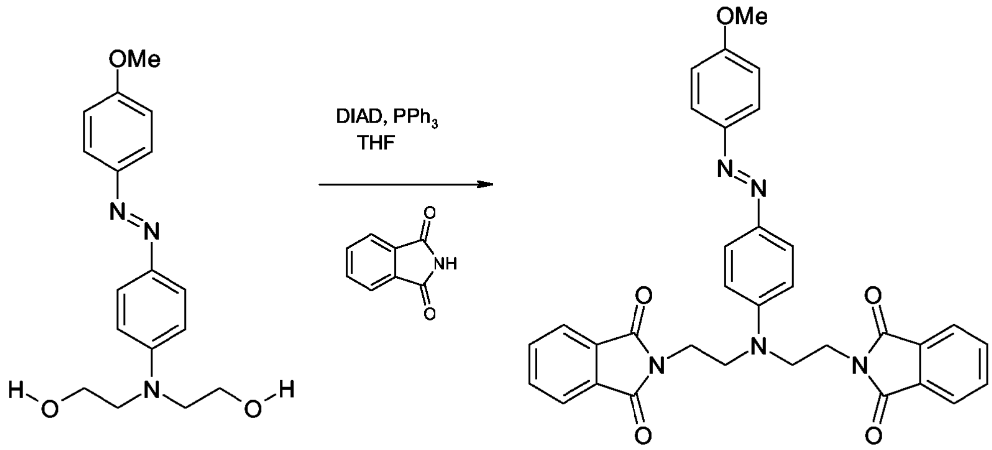
Dye 16

[0081] 5.9 g (33 mmol) CDI was added to a suspension of 3.8 g (30 mmol) 2-amino-4-hydroxy-6-methylpyrimidine. The reaction is slightly exothermic and the mixture remains a suspension. The mixture is stirred for 30 minutes. 7.2 g of reference dye-5 is dissolved in 50 mL dimethylacetamide at 50°C by adding 5.6 mL triethylamine. This solution is added to the suspension of CDI activated 2-amino-4-hydroxy-6-methylpyrimidine and the reaction is allowed to continue over night at room temperature. The precipitated mixture of products is isolated by filtration, washed with ethylacetate and dried. The compound was purified using preparative chromatography using a gradient elution from methanol/water 10/90 to methanol/water 90/10, both buffered with 1.05 mL triethylamine and 0.5 mL acetic acid per liter eluent, on a Kromasil C18 (100A, 10µm)silica. The chromatography was run on a Prochrom LC80 column at a speed of 150 mL per minute and a gradient elution time of 30 minutes. Dye-16 was isolated with 10% yield and characterized by 1H-NMR spectroscopy and mass spectroscopy.

Synthesis Example 18:synthesis of Dye-21

Synthesis of the diphthalimide.

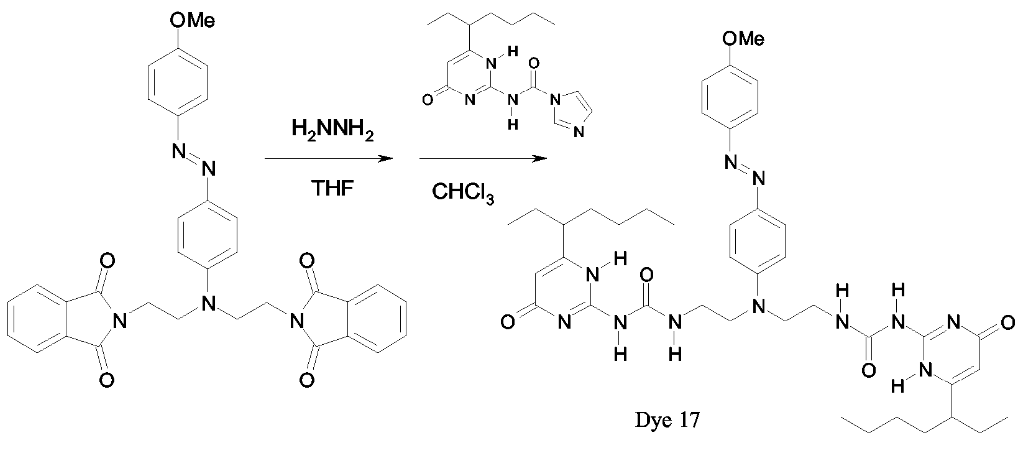
[0082]



[0083] The azodye-diol (1 gram; 3.17 mmol (prepared according to standard procedures) was dissolved in 20 mL of THF together with phthalimide (1.4 gram; 9.5 mmol) and triphenylphosphine (2.4 gram; 9.1 mmol). Diisopropylazodicarboxylate (1.9 gram; 9.4 mmol) in THF was added dropwise to this solution while cooling the mixture in a water bath. Overnight stirring at room temperature yielded a precipitate. Ether was added, stirring was continued for some time and the precipitate was collected by filtration. Yield: 1.43 gram (78%). The diphthalimide was pure according to TLC and NMR analyses.
^{1}H NMR ($CDCl_3$), δ = 7.9-7.6 (12H, m), 7.0 (4H, 2), 3.95 (4H, m), 3.9 (3H, s), 3.8 (4H, m).

Synthesis of Dye-17.

[0084]

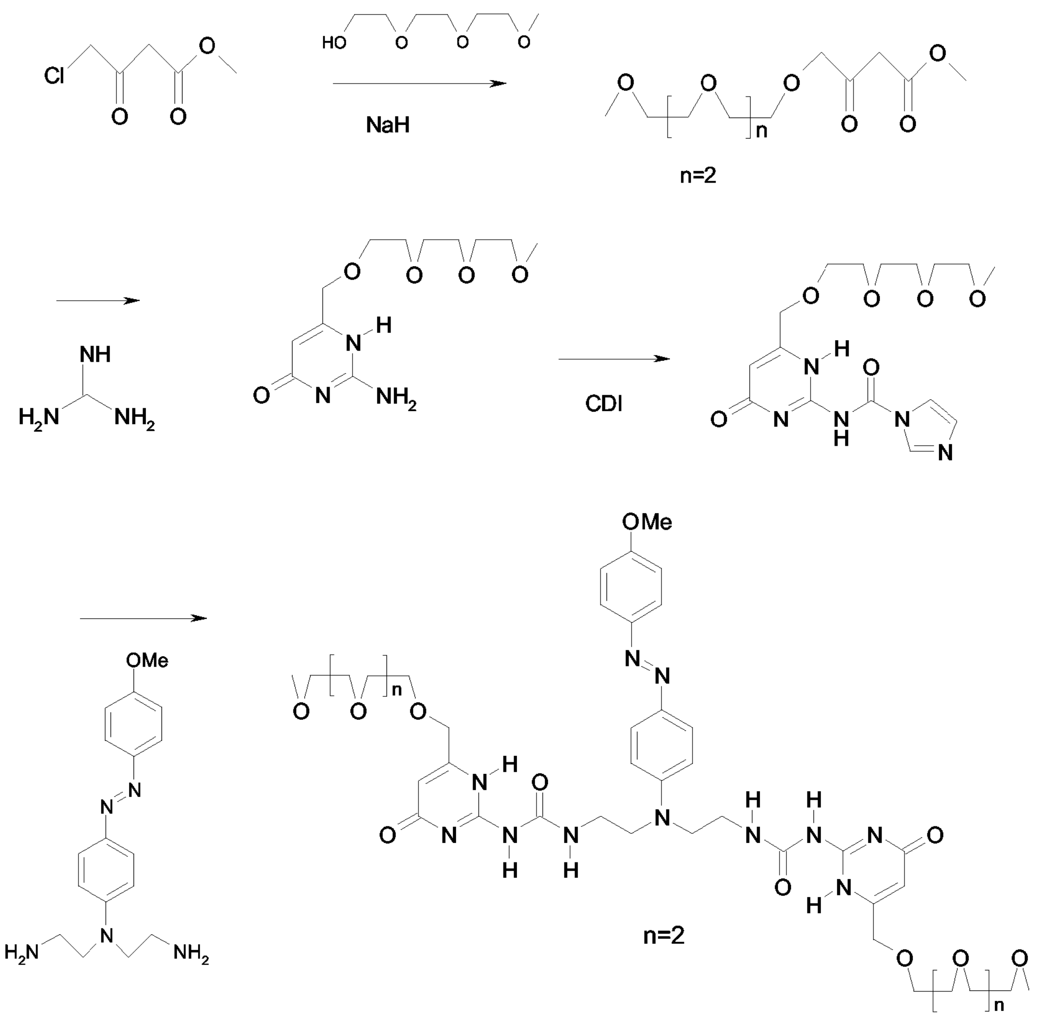


The diphthalimide (1.43 gram; 2.5 mmol) was suspended in 40 mL of boiling THF and hydrazine hydrate (2.6 mL). The suspension developed into a clear solution and subsequently a white precipitate was formed. After cooling down the mixture it was filtered and the filtrate was concentrated to yield the crude diamine that was used in the next step. The CDI-activated product of (1-ethylpentyl)-isocytosine (2.1 gram, 6.93 mmol) was stirred overnight at room temperature

in 50 mL $CHCl_3$ together with the crude diamine (0.87 gram; 2.78 mmol). The mixture was subsequently washed with a HCl solution and a $NaHCO_3$ solution, and thereafter dried and concentrated. The product was precipitated from $CHCl_3$ into methanol and yielded 1.92 gram of Dye-17 as a yellow product (87%).
1H NMR ($CDCl_3$), δ = 13.2 (2H, s), 11.9 (2H, s), 10.4 (2H, s), 7.8 (4H, m), 7.0 (4H, m), 5.8 (2H, s), 3.8 (3H, s), 3.7-3.4 (8H, m), 2.3 (2H, m), 1.8-1.5 (8H, m), 1.3 (8H, m), 0.95-0.8 (12H, m).
MALDI-TOF MS, [M+H+] = 784.6, [M+Na+] = 806.6, [M+K+] = 822.6
UV: λmax = 408 nm; ε = 14000 ($CHCl_3$).

Synthesis Example 19: synthesis of Dye-18

[0085]



Dye 18

[0086] NaH (60%, 1.2 g, 30 mmol) was stirred in 20 mL dry THF under an argon atmosphere. Triethylene glycol (2 g, 12.2 mmol) in 5 mL THF was added dropwise, and after 30 minutes of stirring the β-keto ester (1.8 g, 12 mmol) in 6 mL THF was added dropwise. The mixture was stirred overnight at room temperature, and was thereafter poured into a 10% aqueous solution of acetic acid. Extraction with CH_2Cl_2, washing of the organic layer with water and a NaCl solution, drying with $MgSO_4$, filtration and concentration gave the crude β-keto ester oil (2.1 g, 63%) that was used in the next step as isolated.

[0087] The β-keto ester (2 g, 7.2 mmol) and guanidine carbonate (1.7 g, 18.9 mmol) were boiled in 40 mL of ethanol for 72 hours. The mixture was concentrated, isopropanol was added and the suspension was filtered to remove the excess of guanidine carbonate. The filtrate was concentrated and eluted over a silica column, first using $CHCl_3$ with

4% MeOH to remove contaminations. The isocytosine, a white solid, could be collected by eluting with $CHCl_3$/MeOH (4%) containing 1% triethylamine. Yield: 1.65 g (80%).

[0088] The isocytosine (1.65 g, 5.7 mmol) was stripped from possible protic solvents by co-evaporation with toluene and was dissolved in 40 mL of $CHCl_3$ that had been pre-dried over molecular sieves. Carbonyl diimidazole, CDI, (1.7 g, 10.5 mmol) was added and the solution was stirred for 8 hours at room temperature; NMR analysis showed that no isocytosine was present anymore. The solution was washed twice with a saturated NaCl solution, dried with $MgSO_4$, and concentrated to give a white product. Yield of the activated product: 1.9 g (90%). The activated isocytosine (1.16 g, 3.0 mmol) was stirred for three days at room temperature with 4-(4-(N,N-bis-(2-amino ethyl)amine)-phenylazo)-anisole (0.45 g, 1.44 mmol) in 25 mL of $CHCl_3$ under an atmosphere of argon. The mixture was washed with an 1M HCl solution and with a $NaHCO_3$ solution. The organic layer was dried with Na_2SO_4 and concentrated to give a yellow solid.

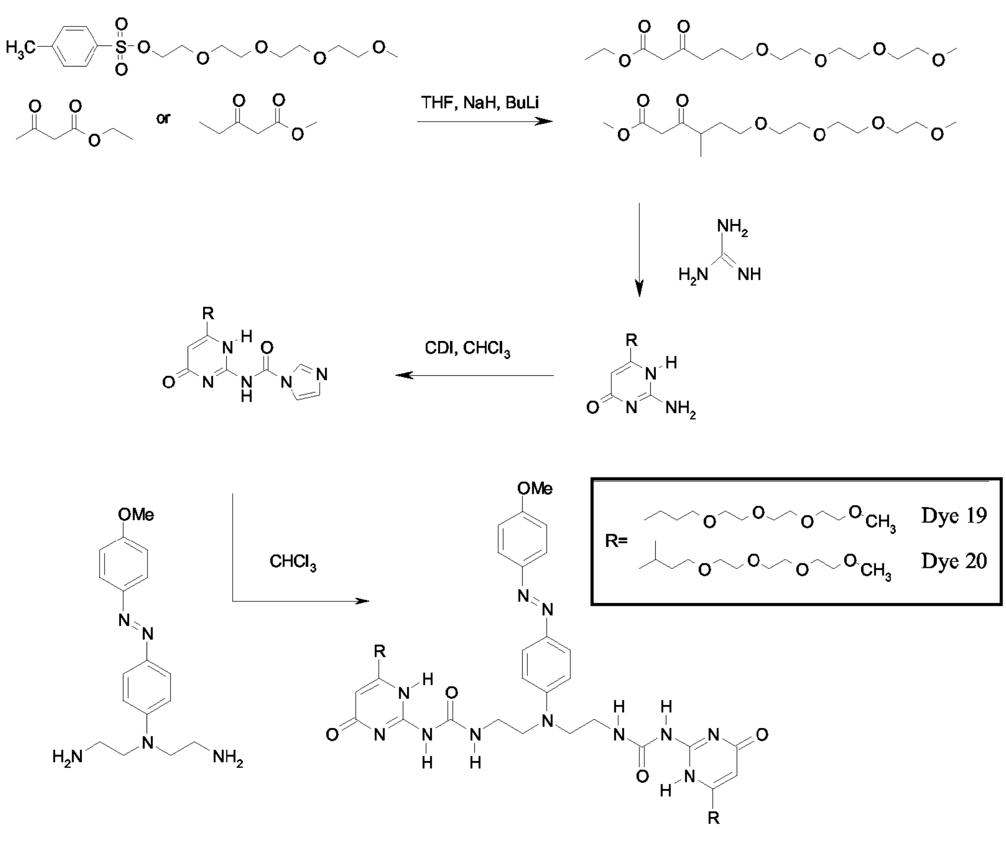
^{1}H NMR (CD_3SOCD_3), δ = 11.0-10.0 (6H, bs), 7.7 (4H, m), 7.0 (4H, m), 5.8 (2H, s), 4.2 (4H, s), 3.8 (4H, s), 3.6-3.3 (31H, m), 3.2 (6H,s). MALDI-TOF MS $C_{43}H_{61}N_{11}O_{13}$, $[M+H^+]$ = 940.3, $[M+Na^+]$ = 962.3, $[M+K^+]$ = 978.3, $[M+2Na^+-H^+]$ = 984.3, $[M+K^++Na^+-H^+]$ = 1000.3.

UV: λ_{max} ($CHCl_3$) = 404 nm; ε = 28000.

NMR-data on the intermediate products are in agreement with the assigned molecular structures.

Synthesis Example 20: synthesis of Dye-19 and Dye-20

[0089]



[0090] Monomethyl tetraethylene glycol (25.8 g, 124 mmol) was stirred in 35 mL of THF, 35 mL of water and NaOH (7.1 g, 178 mmol). The mixture was kept under 5 °C, while TsCl (21.5 g, 113 mmol) in 35 mL of THF was added dropwise; stirring was continued for an additional 4 hours. $CHCl_3$ was added to the solution, and the mixture was washed twice with a saturated NaCl solution. Drying with $MgSO_4$, filtration and concentration gave 37.2 grams of an oily tosylate (91%).

[0091] **Dye-19.** Ethylacetoacetate (2.0 g, 15.4 mmol) was added dropwise to an ice-cooled suspension of NaH (60%, 0.73 g, 18.3 mmol) in 45 mL of dry THF. After one hour of stirring, n-BuLi in hexanes (1.6 M, 9.5 mL, 15.2 mmol) was added, while maintaining ice-cooling of the reaction mixture. After another hour, the monomethyl tetraethylene glycol tosylate (5 g, 13.8 mmol) in 15 mL of dry THF was added dropwise to the ethylacetoacetate mixture and the suspension was put to reflux for 16 hours. The reaction mixture was poured into water and extracted with CH_2Cl_2. The organic layer was washed with a saturated NaCl solution, and dried with Na_2SO_4. Silica column chromatography using 5% dimethoxyethane in $CHCl_3$ gave 3.2 g β-keto ester product (72%).

[0092] The β-keto ester (1.9 g, 5.9 mmol) and guanidine carbonate (1.35 g, 15 mmol) were boiled in 30 mL of ethanol for 16 hours. The mixture was concentrated and eluted over a silica column, first using $CHCl_3$ with 4% MeOH to remove contaminations. The isocytosine, a white solid, was collected by eluting with $CHCl_3$/MeOH (4%) containing 2% triethylamine. Yield: 0.82 g (44%).

The isocytosine (0.82 g, 2.6 mmol) was co-evaporated with toluene and stirred for 6 hours with CDI (0.55 g, 3.4 mmol) in 20 mL of dry $CHCl_3$ under an argon atmosphere. The mixture was washed twice with a saturated NaCl solution, dried with Na_2SO_4 and concentrated.

The activated product (0.8 g, 1.95 mmol) was stirred with 4-(4-(N,N-bis-(2-amino ethyl)amine)-phenylazo)-anisole (0.26 g, 0.83 mmol) in 25 mL of $CHCl_3$. After 24 hours, the solution was washed with a 1M HCl and thereafter with a $NaHCO_3$ solution. Drying with Na_2SO_4 was followed by filtration and concentration to yield Dye-19 as a yellow solid. The solid was dissolved in $CHCl_3$ and precipitated into pentane. Yield: 0.77 g (95%).

^{1}H NMR ($CDCl_3$), δ = 13.0 (2H, bs), 11.9 (2H, bs), 10.4 (2H, bs), 7.8 (4H, m), 6.9 (4H, m), 5.9 (2H, s), 3.9-3.3 (45H, m), 2.6 (4H, t), 1.9 (4H, t).

MALDI-TOF MS $C_{47}H_{69}N_{11}O_{13}$, [M+H$^+$] = 996.5, [M+Na$^+$] = 1018.5.

UV: λ_{max} ($CHCl_3$) = 404 nm; ε = 15000 NMR-data on the intermediate products are in agreement with the assigned molecular structures.

[0093] **Dye-20.** THF (25 mL) was added to NaH (60%, 0.64 g, 16 mmol) which was previously washed with pentane. Methylpropionylacetate (1.5 g, 11.5 mmol) was added, while the suspension was cooled in an ice bath. After 10 minutes of stirring, n-BuLi in hexanes (2.5 M, 4.8 mL, 12 mmol) was added dropwise. Another 10 minutes of stirring was followed by addition of the monomethyl tetraethyleneglycol tosylate (4.6 g, 12.7 mmol) in 15 mL of THF. The mixture was boiled overnight, and then washed with a 1M HCl solution and a saturated NaCl solution. The β-keto ester was purified by silica column chromatography using consecutively $CHCl_3$/MeOH (2%), and $CHCl_3$/MeOH (4%) containing 2% triethylamine as eluents.

The β-keto ester (1.6 g, 5.0 mmol) and guanidine carbonate (1.15 g, 12.8 mmol) were boiled in 20 mL of ethanol for 16 hours. The mixture was concentrated and eluted over a silica column, first using $CHCl_3$ with 4% MeOH to remove contaminations. The isocytosine was collected as a white solid by eluting with $CHCl_3$/MeOH (4%) containing 2% triethylamine. Yield: 1.36 g (83%).

The isocytosine (1.36 g, 4.1 mmol) was stripped from protic contaminants by co-evaporation with toluene and was dissolved in 25 mL of dry $CHCl_3$. CDI (1.05 g, 6.5 mmol) was added and stirring was maintained overnight under an argon atmosphere. The mixture was washed twice with a saturated NaCl solution, dried with Na_2SO_4 and concentrated.

The activated product (1.9 g, 4.5 mmol) was stirred with 4-(4-(N,N-bis-(2-amino ethyl)amine)-phenylazo)-anisole (0.55 g, 1.76 mmol) in 50 mL of dry $CHCl_3$. After 24 hours, the solution was washed with a 1M HCl solution and thereafter with a $NaHCO_3$ solution. Drying with Na_2SO_4 was followed by filtration and concentration to give Dye-20 as a yellow solid. The solid was dissolved in $CHCl_3$ and precipitated into pentane, followed by crystallization from ethylacetate. Yield: 1.55 (87%).

^{1}H NMR ($CDCl_3$), δ = 13.1 (2H, bs), 11.9 (2H, bs), 10.4 (2H, bs), 7.8 (4H, m), 6.9 (4H, m), 5.9 (2H, s), 3.9-3.3 (45H, m), 2.9 (2H, m), 1.9 (4H, t), 1.3 (6H, d).

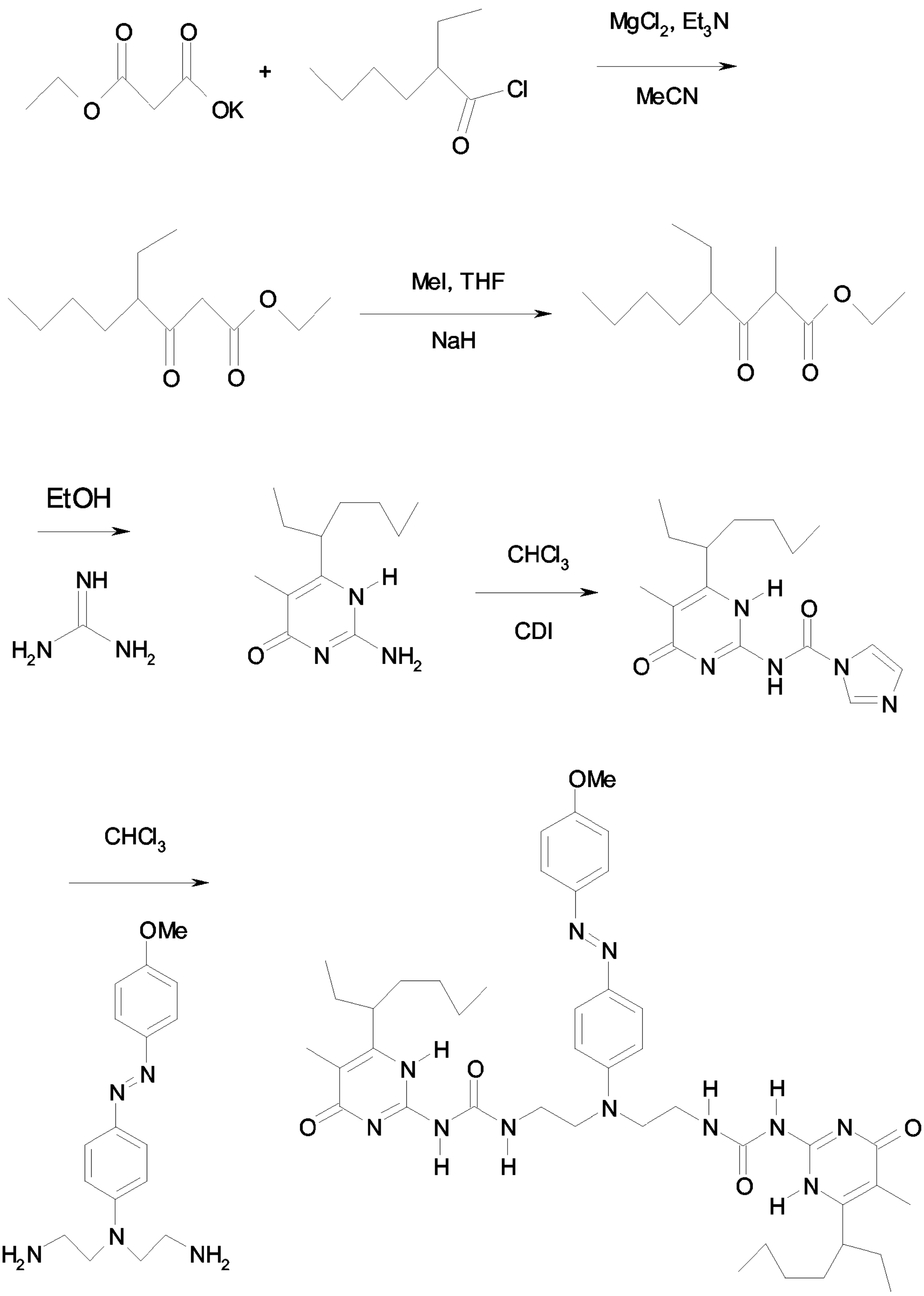
MALDI-TOF MS $C_{49}H_{73}N_{11}O_{13}$, [M+H$^+$] = 1024.5, [M+Na$^+$] = 1046.5.

UV: λ_{max} ($CHCl_3$) = 404 nm; ε ($CHCl_3$) = 16000

NMR-data on the intermediate products are in agreement with the assigned molecular structures.

<u>Synthesis Example 21</u>: synthesis of Dye-21

[0094] $MgCl_2$ (16.5 g, 173 mmol) was added to a cooled (-15 °C) mixture of potassium malonate (24.4 g, 144 mmol) and triethylamine (22.5 g, 223 mmol) in 200 mL acetonitrile. After stirring for 2 hours at 10-15 °C, ethylhexanoyl chloride (11.2 g, 69 mmol) was added, while maintaining cooling in an ice bath. Overnight stirring at room temperature under an argon atmosphere was followed by evaporation of the solvent, addition of ether and an HCl solution. The organic layer was washed with a bicarbonate solution, dried over $MgSO_4$ and concentrated to give an almost quantitative yield of an oil. This β-keto ethyl ester (6.0 g, 28.0 mmol) was added dropwise to an ice cooled suspension of NaH (60%, 1.32 g, 33 mmol) in 75 mL of dried THF.



Dye 21

[0095] After an hour of stirring, MeI (2.4 mL, 38.5 mmol) was added and the mixture was stirred overnight under an argon atmosphere at 45 °C. The product was poured into an aqueous 1M HCl solution and extracted with chloroform. The organic layer was washed with a saturated NaCl solution and dried with Na_2SO_4. Evaporation of the solvent gave

6.5 grams of an oil. This modified β-keto ethyl ester (11.2 g, 49.1 mmol) and guanidine carbonate (42.2 g, 469 mmol) were put to reflux in 275 mL of ethanol. Reflux was maintained during two days, using a Dean-Stark setup with dried molecular sieves in the receiving arm. Ethanol was removed by evaporation, chloroform was added and the organic solution was washed with a bicarbonate solution. Drying of the solution with $MgSO_4$ was followed by precipitation of the isocytosine into pentane to afford 6.0 grams (55%) of a white solid. The isocytosine (3.0 g, 13.5 mmol) and CDI (3.0 g, 18.5 mmol) were stirred during two hours in 75 mL of chloroform at room temperature. The mixture was washed three times with a saturated NaCl solution and then dried with Na_2SO_4. The activated product (3.9 g, 90%) was ready for use in the next step as NMR-analysis did not show any imidazole or CDI traces. The activated isocytosine (3.9 g, 12.3 mmol) was stirred overnight with 4-(4-(N,N-bis-(2-amino ethyl)amine)-phenylazo)-anisole (1.47 g, 4.7 mmol) in 120 mL of chloroform. The mixture was consecutively extracted with a 1 M aqueous HCl solution and a bicarbonate solution, followed by drying over Na_2SO_4. Evaporation of the solvent was followed by precipitation from chloroform into methanol, and then from chloroform into pentane to yield 1.5 grams of Dye-21 as a yellow solid.

^{1}H NMR ($CDCl_3$), δ = 13.0 (2H, bs), 11.9 (2H, bs), 10.5 (2H, bs), 7.8 (4H, m), 7.0 (2H, m), 6.9 (2H, m), 3.8 (3H, s), 3.7 (4H, m), 3.5 (4H, m), 2.8 (2H, m), 2.1 (6H, s), 1.8-1.5 (8H, m), 1.4-1.2 (8H, m), 0.9 (12H, m).

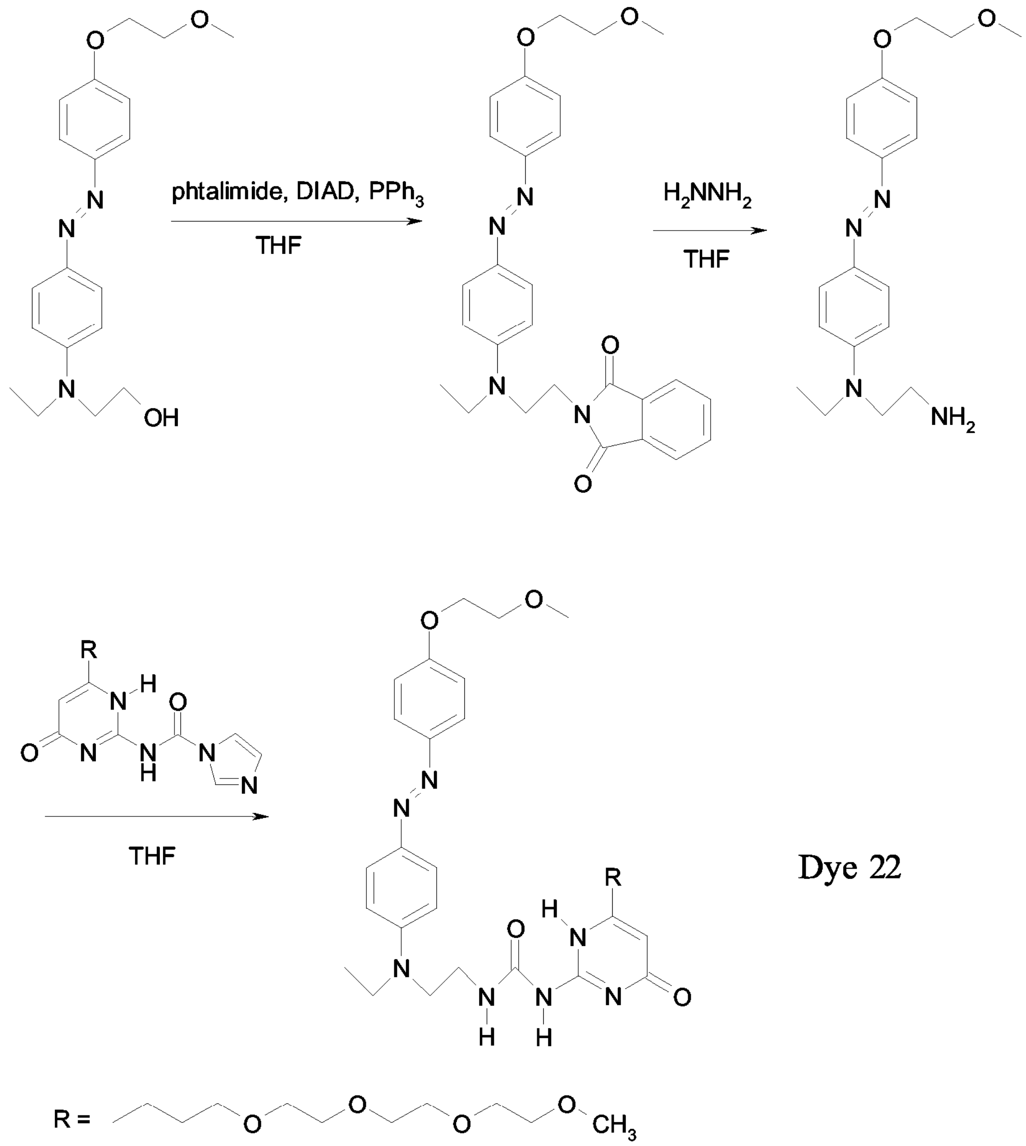
MALDI-TOF MS $C_{43}H_{61}N_{11}O_5$, $[M+H^+]$ = 812.1, $[M+Na^+]$ = 834.1.

UV: λ_{max} ($CHCl_3$) = 410 nm; ε ($CHCl_3$) = 22000

NMR-data on the intermediate products are in agreement with the assigned molecular structures.

Synthesis Example 22: synthesis of Dye-22

[0096]



Dye 22

[0097] The CDI-activated glycolated isocytosine has been described in Example 11.

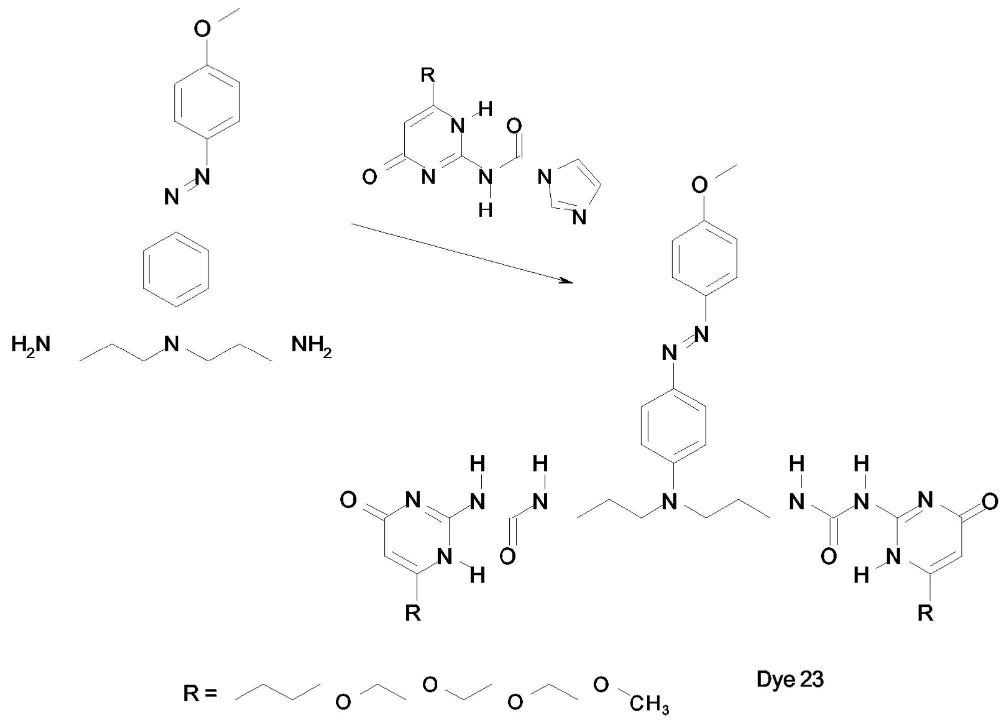
The dye alcohol (10 g, 29.2 mmol; prepared according to standard procedures), phthalimide (5.1 g, 34.7 mmol) and triphenylphosphine (9.2 g, 35.1 mmol) were dissolved in 200 mL THF. DIAD (7.1 g, 35.1 mmol) was added dropwise at room temperature. After overnight reaction, the product was concentrated and purified on a silica column ($CHCl_3$/MeOH, 1%). Stirring in ether/THF 20/1 gave a precipitate that was filtered and dried. Yield: 11.9 g (86%). Hydrazine hydrate (2 g, 40 mmol) was added to the phthalimide dye (11.9 g, 25.2 mmol) in boiling THF. After overnight reflux the white precipitate was removed by filtration. The filtrate was stirred overnight at 40 °C after an additional portion of hydrazine hydrate (1.5 g, 30 mmol) was added. Filtration and co-evaporation of the filtrate with toluene gave the amine product. This amine (1.35 g, 3.9 mmol) and the activated isocytosine (2.2 g, 5.4 mmol) were stirred overnight at room temperature in 20 mL of THF. The solution was concentrated, $CHCl_3$ was added and the organic solution was washed consecutively with 0.01 M HCl, salt and bicarbonate solutions. After drying on $MgSO_4$ the residue was purified by column chromatography on silica using $CHCl_3$/MeOH 1% to 4% as eluent. 1.54 g of Dye-22 was obtained(57%).

^1H NMR ($CDCl_3$), δ = 13.0 (1H, bs), 11.9 (1H, bs), 10.4 (1H, bs), 7.8 (4H, m), 7.0 (2H, m), 6.8 (2H, m), 5.8 (1H, s), 4.2

(2H, t), 3.8 (2H, m), 3.7-3.4 (26H, m), 2.7 (2H, t), 2.0 (2H, m), 1.3 (3H, t). MALDI-TOF MS $C_{34}H_{49}N_7O_8$, $[M+H^+]$ = 684.1, $[M+Na^+]$ = 706.1.
UV: λ_{max} ($CHCl_3$) = 413 nm; ε = 17000 NMR-data on the intermediate products are in agreement with the assigned molecular structures.

Synthesis Example 23: synthesis of Dye-23

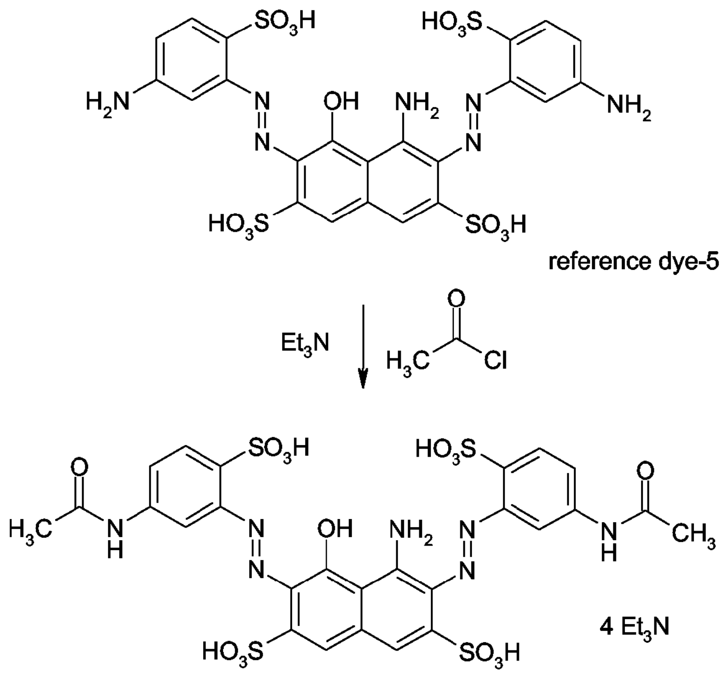
[0098]



[0099] The CDI-activated glycolated isocytosine has been described in Example 11. The diamine (0.7 g, 2.1 mmol) and the CDI-activated isocytosine (2.0 g, 4.9 mmol) were stirred overnight in 20 mL of THF at room temperature under an argon atmosphere. Chloroform was added and the mixture was washed with a 0.01 M HCl solution and a saturated bicarbonate solution. The organic phase is dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue is purified by column chromatography over silica using $CHCl_3$/MeOH (2%) as eluent to yield 0.95 g of pure Dye-23.
^1H NMR ($CDCl_3$), δ = 13.2 (1H, s), 13.0 (1H, s), 11.9 (1H, s), 11.7 (1H, s), 10.2 (1H, s), 10.0 (1H, s), 7.8 (4H, m), 7.0 (2H, m), 6.8 (2H, m), 5.8 (1H, s), 5.7 (1H, s), 3.9 (6H, s), 4.0-3.3 (39H, m), 3.1 (2H, m), 2.5 (4H, m), 2.1 (2H, m), 1.8 (4H, m).
MALDI-TOF MS $C_{49}H_{73}N_{11}O_{13}$, $[M+H^+]$ = 1024.4, $[M+Na^+]$ = 1046.4.
UV: λ_{max} ($CHCl_3$) = 418 nm; ε = 24000

Synthesis Example 24: synthesis of Reference Dye-6

[0100]



reference dye-5

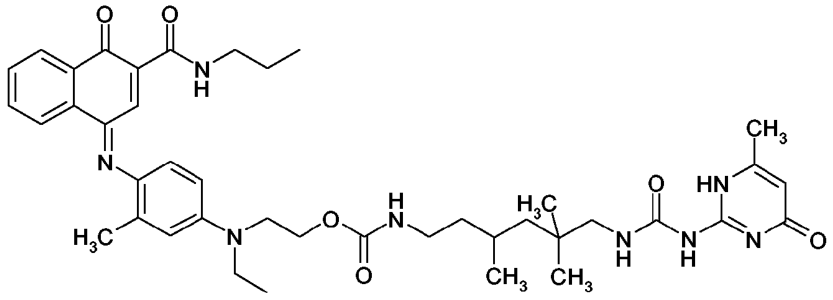
reference dye-6

[0101] 0.9 g (11 mmol) acetyl chloride in 5 mL dimethylacetamide was added dropwise at 35°C to a suspension of 3.6 g (5 mmol) of reference dye-5 and 2.8 mL (20 mmol) triethylamine in 50 mL dimethylacetamide. The reaction is slightly exothermic but remains a suspension. The reaction is allowed to continue over night at room temperature. The precipitated compound is isolated by filtration and washed with ethyl acetate. Reference dye-6 is re-suspended in 25-mL ethyl acetate, isolated by filtration and dried. From the combined filtrates, a second crop precipitates and is isolated by filtration and washed with methylene chloride. The two fractions were combined yielding 4.2 g of reference dye-6 (70%). Reference dye-6 was characterized by ^{1}H-NMR spectroscopy and mass spectroscopy.

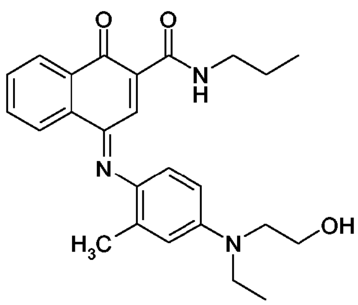
EVALUATION EXAMPLES

Example 1

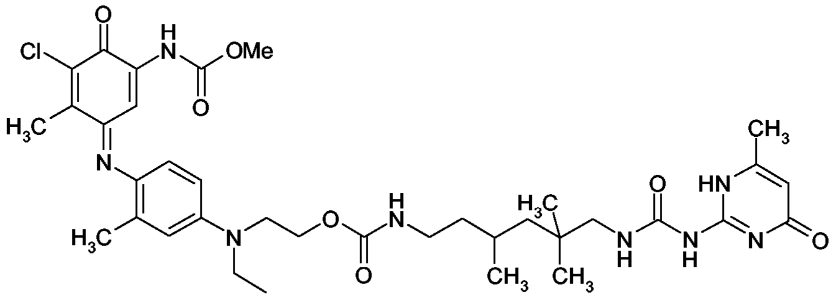
[0102] In this example a comparison is made between the light-fastness characteristics of some invention dyes and some reference dyes. The following compounds were involved :



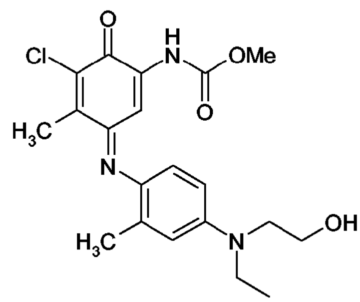
invention dye-8



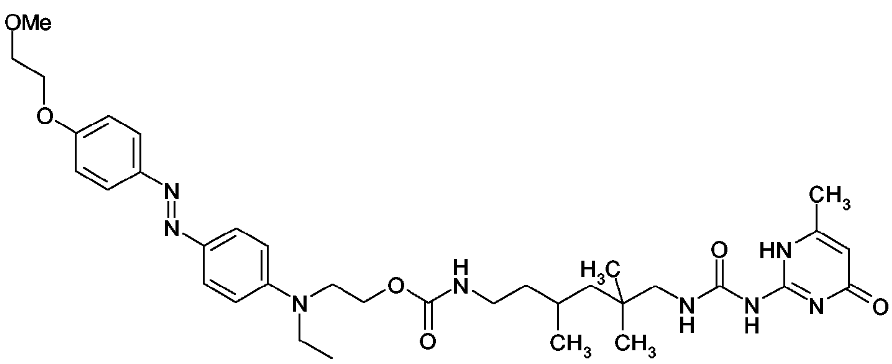
reference dye-1



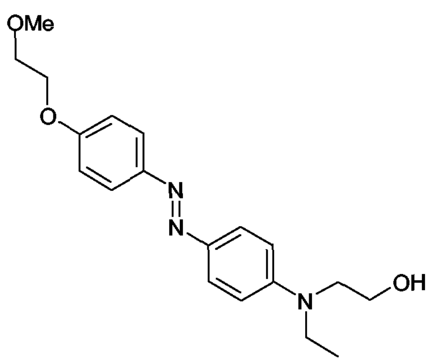
invention dye-6



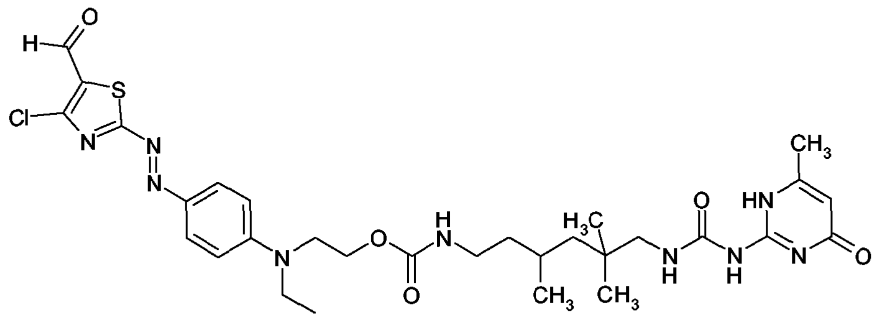
reference dye-2



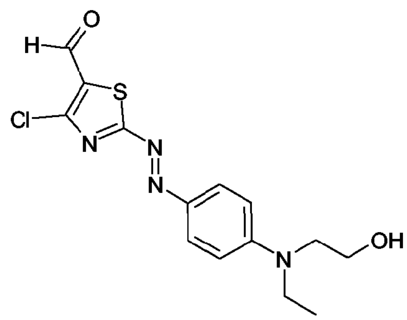
invention dye-9



reference dye-3



invention dye-7



reference dye-4

[0103] Both reference and invention dyes were dissolved in 2-butanone as a 0.015 molar solution. Samples of 5 mL of the dye solutions were diluted with 5 mL methanol. From each sample, 20 µl of each solution was spotted on a Polar DTR receiver (trademark from AGFA) using an Anachem SK233 apparatus. Each sample was spotted 5 times and the average density value was taken as initial density for each dye at the start of the light-fastness test. The spotted samples were exposed during 8 hours using a Xenon-apparatus (Xenotest 150, equipped with a 7IR-filter, working in indoor mode). After one, two, four and eight hours, the density was measured again and the average density of the five spots was taken as the residual density. The percentage residual density is expressed as (residual density / initial density) x 100. The results are summarized in Table 2.

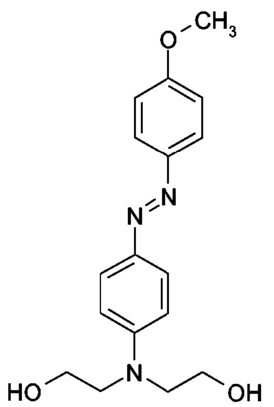
Table 2.

Dye	1 h exposure % residual density	2 h exposure % residual density	4 h exposure % residual density	8 h exposure % residual density
Invention dye-8	86	78	73	42
Reference dye-1	75	60	36	21
Invention dye-6	92	89	80	61
Reference dye-2	90	71	58	34
Invention dye-9	99	97	77	63
Reference dye-3	94	81	58	39
Invention dye-7	99	87	77	56
Reference dye-4	89	73	58	33

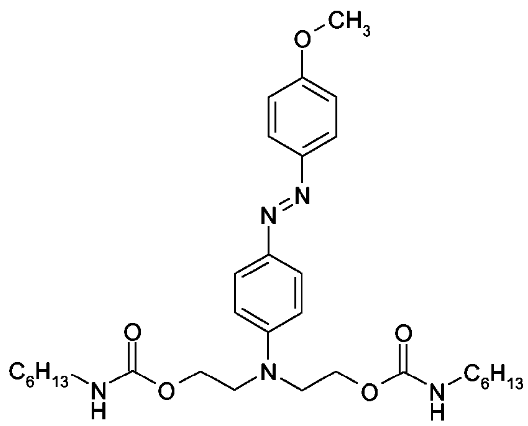
[0104] The results shown in Table 2 clearly show that use of the self-assembling dyes, according to the present invention, in ink compositions results in significantly higher light-fastness.

Example 2

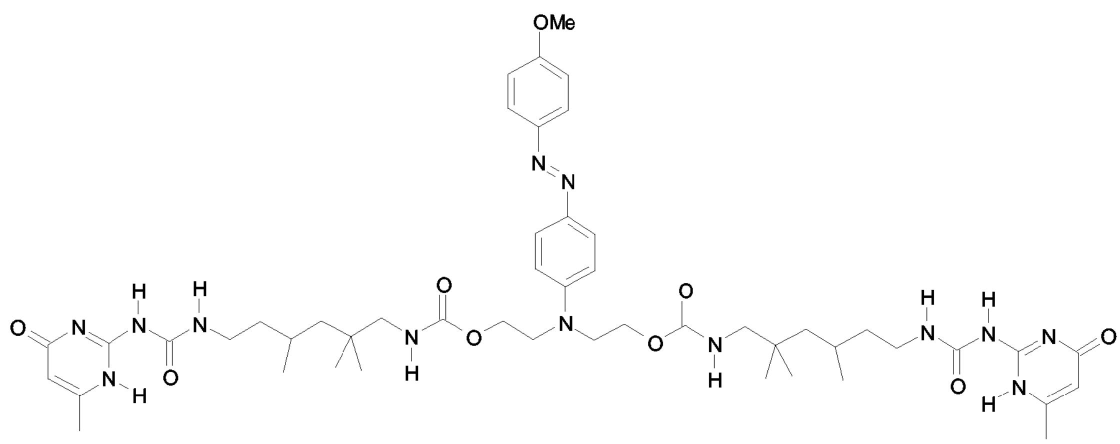
[0105] In this example a comparison is made between the light-fastness characteristics of some invention dyes and some reference dyes. The following compounds were involved :



reference dye-7



reference dye-8



Dye 15

[0106] Both reference compounds and the invention dye were dissolved in CH_2Cl_2/2-methoxypropanol (1/1). Reference dye-7 was dissolved as a 0.25% solution (w/v). The reference dye-8 and the invention dye-16 were dissolved as a 0.5 % solution (w/v). 1 mL of the samples was diluted with 0.75 mL 2-methoxypropanol and 0.75 mL CH_2Cl_2. A second sample of 1 mL was diluted with 1.75 mL 2-methoxypropanol and 2 mL CH_2Cl_2. For each sample 10 µl was spotted on a Polar DTR receiver (trademark from AGFA). Each sample was spotted 5 times and the average value was taken as the initial density for each dye at the start of the light-fastness test. The spotted samples were exposed during 8 hours using a Xenon-apparatus (Xenotest 150, equipped with a 7IR-filter, working in indoor mode). After one, two, four and eight hours, the density was measured again and the average density of five spots was taken as the residual density. The percentage residual density is expressed as (residual density/initial density) x 100. The results are summarized in Table 3 and represent the percentages for the initial samples. The percentage residual density for both the initial samples and the diluted samples showed the same degradation rate.

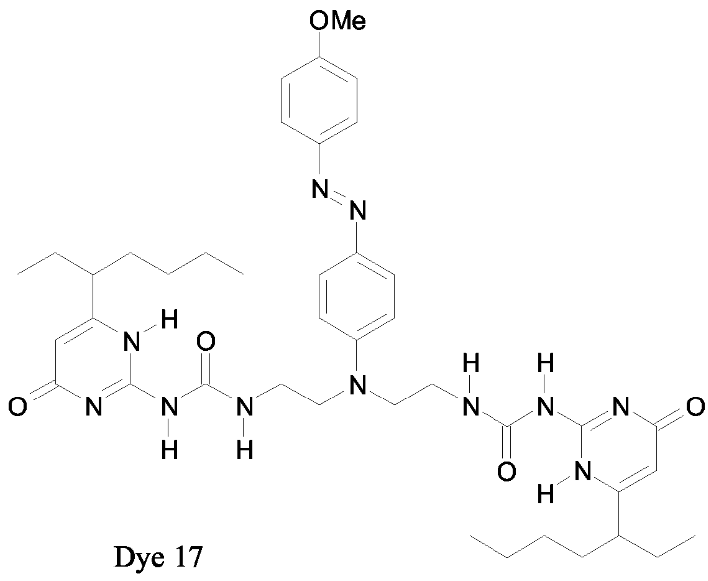
Table 3.

Dye	1 hr exposure % residual density	2 hrs exposure % residual density	4 hrs exposure % residual density	8 hrs exposure % residual density
Invention dye-15	100	100	100	90
Reference dye-7	100	95	82	68
Reference dye-8	100	100	95	75

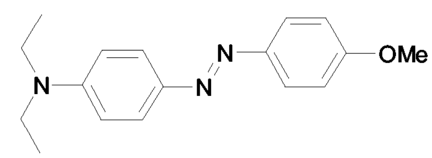
[0107] The results shown in Table 3 clearly show that ink compositions with self-assembling dyes, according to the present invention, containing a multiple hydrogen bonding moiety, have a significantly higher light-fastness.

Example 3

[0108] In this example a comparison is made between the light-fastness characteristics of some invention dyes and some reference dyes. The following compounds were involved :



Dye 17



reference dye-9

[0109] Both reference dye-9 and the invention Dye-17 were dissolved in CH_2Cl_2/2-methoxypropanol (1/1). Reference dye-9 was dissolved as a 0.25% solution (w/v). The invention Dye-17 was dissolved as a 0.5 % solution (w/v). 1 mL of the samples was diluted with 0.75 mL 2-methoxypropanol and 0.75 mL CH_2Cl_2. A second sample of 1 mL was diluted with 1.75 mL 2-methoxypropanol and 2 mL CH_2Cl_2. For each sample 10 μl was spotted on a Polar DTR receiver (trademark from AGFA). Each sample was spotted 5 times and the average value was taken as the initial density for each dye at the start of the light-fastness test. The spotted samples were exposed during 8 hours using a Xenon-apparatus (Xenotest 150, equipped with a 7IR-filter, working in indoor mode). After one, two, four and eight hours, the density was measured again and the average density of five spots was taken as the residual density. The percentage residual density is expressed as (residual density/initial density) x 100. The results are summarized in Table 4 and represent the percentages for the initial samples. The percentage residual density for both the initial samples and the diluted samples showed the same degradation rate.

Table 4

Dye	1 hr exposure % residual density	2 hrs exposure % residual density	4 hrs exposure % residual density	8 hrs exposure % residual density
Invention dye-17	100	100	100	100
Reference dye-9	92	85	77	55

[0110] The results shown in Table 4 clearly show that ink compositions with self-assembling dyes according to the present invention, containing a multiple hydrogen bonding moiety, have a significantly higher light-fastness.

Example 4

[0111] This example deals with ink preparation and the evaluation of some physical properties.

Solubility.

[0112] A 5% solution of Dye-6, Dye-7 and Dye-9 in butyl lactate, ethyl lactate, diacetone alcohol, propylene glycol methyl ether and tripropylene glycol methyl ether were prepared by adding the dyes to the solvents and sonicating the suspension for one hour. Clear solutions were obtained. Reference magenta dye RM1 (Table 7) was only partially soluble under the same conditions; reference cyan dye RC1 (Table 7) was soluble in butyl lactate (5%) but only partially soluble in the other solvents. Reference yellow dye RY1 (Table 7) was only soluble in methoxypropyl acetate and N-methyl pyrrolidinone.

Inks.

[0113] Table 5 shows the basic formulation, which the dyes were assessed in. The ink raw materials were placed into a plastic bottle and sonicated for one hour. The inks were then filtered to 1 μm and the physical properties measured. Table 6 shows the physical property measurements for each ink. The dyes according to the invention have similar physical ink properties and the filtration times are all good. Generally a filtration time of less than 45 seconds is expected for a dye-based ink.

Table 5.

Ink	**%Composition w/w**
Dye (Dye-6;Dye-7)	3
Vinyl chloride/vinyl acetate copolymer UCAR VAGD	2
Butyl lactate	95
Ink	**%Composition w/w**
Dye (Dye-9)	3
Vinyl chloride/vinyl acetate copolymer UCAR VAGD	2
Butyl lactate	75
N-Methyl Pyrrolidone	20

Priming and Loading.

[0114] Inks Ink 1-6 (see table 7 for reference dyes) were tested under standard operating conditions in a Trident

UltraJet printhead. The standard conditions are defined as :

a. 150V printhead driver
b. printhead temperature = 25°C
c. sub-pulse off
d. 354 dpi

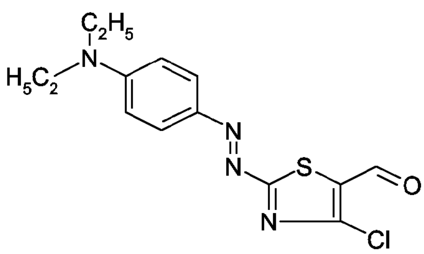
[0115] The results obtained show that all inks are easy to load and prime, and achieve good wetting of the internal architecture of the printhead. No visible air entrapment is noticed. Initial start-up is almost immediate and all channels work after maximum 4 primes. The print quality is very good on AGFA Outdoor Material (Polar DTR receiver; trademark from AGFA) and good on polyester (Melinex 347) and PVC substrates.

Table 6.

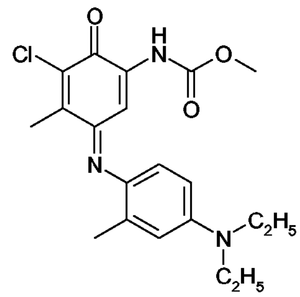
	Ink1/Dye-6 Cyan	**Ink2/Dye-7 Magenta**	**Ink3/RM1 Magenta**	**Ink4/RC1 Cyan**
Viscosity (mPa.s)	7.70	8.24	7.15	8.27
Surface Tension dynes/cm	31.5	31.5	31.5	31.5
Filtration Performance[1]	27 sec.	26 sec.	29 sec.	28 sec.
	Ink5/Dye-9 Yellow	**Ink6/RY1 Yellow**		
Viscosity (mPa.s)	8.44	7.56		
Surface Tension dynes/cm	31.5	30		
Filtration Performance[1]	33	33		

[1] : the filtration performance is the time taken to filter 15 mL of ink through a one µm filter paper using a vacuum of 200 mm Hg.

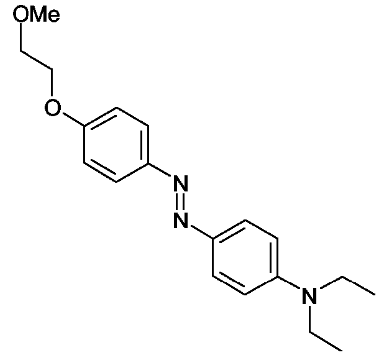
Table 7.



Reference Magenta-1 (RM1)



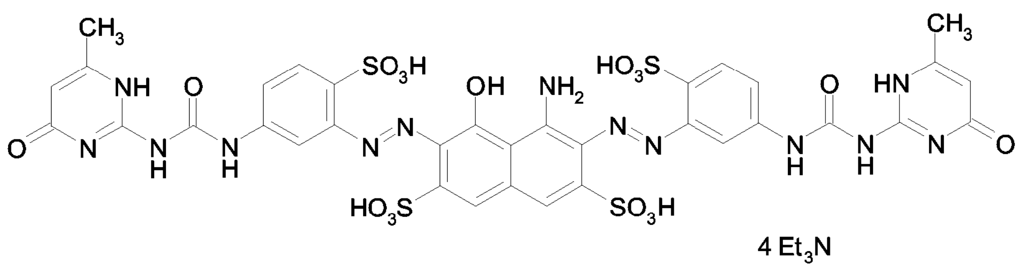
Reference Cyan-1 (RC1)



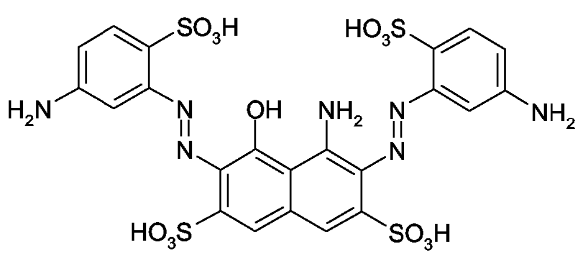
Reference Yellow-1 (RY1)

Example 5

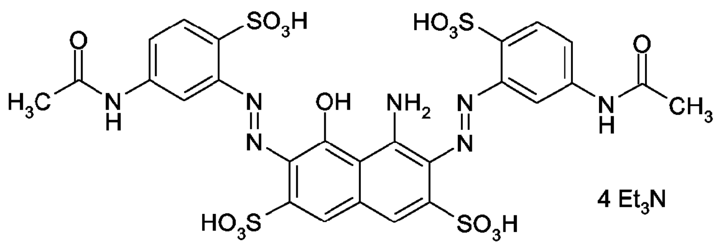
[0116] A 0.02 M solution of reference dye-5, reference dye-6 and invention dye-16 were dissolved in water/MeOH 90/10 and diluted twice and five times. The solutions were spotted onto an AGFA POLAR DTR outdoor medium and exposed to Xenon light for eight hours. The % density loss at density 1 was measured after eight hours exposure. The results are summarized in Table 8.



Dye 16



Reference dye-5



Reference dye-6

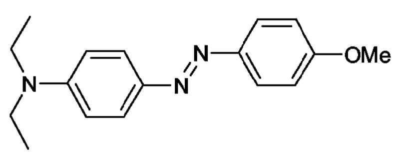
Table 8.

Sample	% density loss after 8 hours exposure at density 1
invention dye-16	1 %
reference dye-6	5 %
reference dye-5	20 %

[0117] This example clearly illustrates that the introduction of a self-assembling unit gives superior light fastness as compared to both the parent amino dye and the acetylated reference dye.

Example 6

[0118] 0.02 M solutions of the invention dyes summarized in Table 11 and reference dye-9 were prepared in CH_2Cl_2/MeOH/ethyl lactate 50/40/10 and diluted twice, four times, eight times and sixteen times. All solutions were sprayed onto an AGFA POLAR DTR outdoor medium, resulting in a density wedge. All samples were exposed to Xenon light for eight hours and the percentage density loss after eight hours exposure was measured at density 1. All results are summarized in Table 9.



Reference dye-9

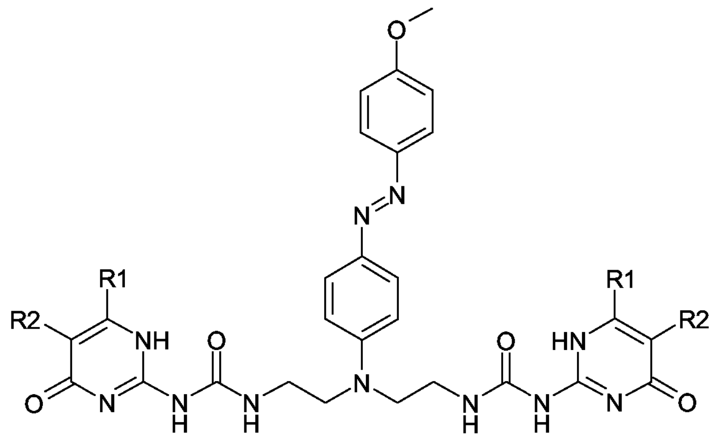


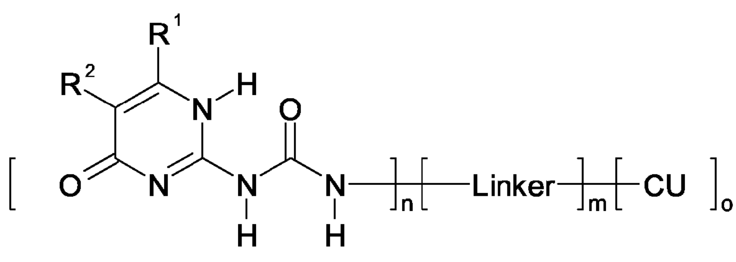
Table 9.

Compound	R1	R2	% density loss at density 1 after eight hours Xenon exposure
invention dye-17	$CH_3(CH_2)_3CHCH_2CH_3$	H	24 %
invention dye-21	$CH_3(CH_2)_3CHCH_2CH_3$	CH_3	29 %
invention dye-19	$-(CH_2)_3O(CH_2CH_2O)_3CH_3$	H	11 %
invention dye-20	$-CH(CH_3)CH_2CH_2O$ $(CH_2CH_2O)_3CH_3$	H	8 %
reference dye-9 (comparative)	-	-	51 %

[0119] From the results in Table 9 it is clear that the introduction of self-assembling units on the basic chromophore group significantly increases the light-fastness of the dyes.

Claims

1. A self-assembling dye according to formula (I):



Formula (I)

wherein
'Linker' represents any linking group;
'CU' means any chromophore group selected from the group consisting of an azo dye with a molar extinction coefficient larger than 10^3 $l.mol^{-1}.cm^{-1}$, an anthraquinone dye, a (poly)methine dye, an azomethine dye, a disazo dye, a carbonium dye, a styryl dye, a stilbene dye, a phthalocyanine dye, a coumarin dye, an aryl-carbonium dye,

a nitro dye, a naphtholactam dye, a dioxazine dye, a flavin dye and a formazan dye;
n and o are the same or different and are integers having a value of at least 1; m can be zero or any integer having a value of at least 1;
R^1 and R^2 are the same or different and represent hydrogen, a halogen, a substituted or unsubstituted alkoxy group, a substituted or unsubstituted thioalkoxy group, a substituted or unsubstituted sulphoxy group, a substituted or unsubstituted sulphone group, a substituted or unsubstituted amino group, a nitrile group, a substituted or unsubstituted, saturated or unsaturated alkyl group, a substituted or unsubstituted acyl group, a substituted or unsubstituted sulphonyl group, a substituted or unsubstituted phosphoryl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted aralkyl group, a heterocyclic group, a CU group, or R^1 and R^2 represent the necessary atoms to form a ring system.

2. A self-assembling dye according to claim 1, wherein said Linker is selected from the group consisting of a substituted or unsubstituted, saturated or unsaturated aliphatic group, a substituted or unsubstituted alicyclic hydrocarbon group, a substituted or unsubstituted aromatic group and a substituted or unsubstituted heteroaromatic group.

3. A self-assembling dye according to claim 1 or 2, wherein the association constant K_{ass} of the self-assembling reaction, determined by ^{1}H-NMR in $CDCl_3$, is at least 2.5 M^{-1}.

4. An self-assembling dye according to claim 1 or 2, wherein said association constant K_{ass} is at least 10^2 M^{-1}.

5. An self-assembling dye according to claim 1 or 2, wherein said association constant K_{ass} is at least 10^5 M^{-1}.

6. An ink-jet ink comprising a self-assembling dye according to any of claims 1 to 5.

7. An ink-jet ink according to claim 6, wherein said ink-jet ink is a water based ink-jet ink.

8. An ink-jet ink according to claim 6, wherein said ink-jet ink is a solvent based ink-jet ink.

9. An ink-jet ink according to claim 6, wherein said ink-jet ink is a oil based ink-jet ink.

10. An ink-jet ink according to claim 6, wherein said ink-jet ink is a hot melt based ink-jet ink.

11. An ink-jet ink according to claim 6, wherein said ink-jet ink is a UV-curable ink-jet ink.

12. A process for the formation of an ink-jet image comprising the step of image-wise jetting ink-jet ink by means of an ink-jet printing apparatus onto an ink-jet recording element, **characterized in that** said ink-jet ink is an ink-jet ink according to any of claims 5 to 11.

13. An ink-jet printing apparatus comprising an ink cartridge containing an ink-jet ink according to any of claims 5 to 11.