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(54) **Title**: NOVEL GEMINI SURFACTANTS AND THEIR USE

(57) **Abstract**: Disclosed herein are gemini surfactants, and methods for making and using these gemini surfactants. These gemini surfactants may be incorporated in paints and coatings to provide hydrophilic and/or self-cleaning properties. Surfactants are compounds composed of both hydrophilic and hydrophobic or lipophilic groups. In view of their dual hydrophilic and hydrophobic nature, surfactants tend to concentrate at the interfaces of aqueous mixtures; the hydrophilic part of the surfactant orients itself towards the aqueous phase and the hydrophobic part orients itself away from the aqueous phase.

NOVEL GEMINI SURFACTANTS AND THEIR USE

BACKGROUND

[0001] Surfactants are compounds composed of both hydrophilic and hydrophobic or lipophilic groups. In view of their dual hydrophilic and hydrophobic nature, surfactants tend to concentrate at the interfaces of aqueous mixtures; the hydrophilic part of the surfactant orients itself towards the aqueous phase and the hydrophobic part orients itself away from the aqueous phase. Due to these properties, surfactants can be used as emulsifiers for emulsion polymerization reactions during the manufacture of paints. Surfactants, in addition, improve wetting of the substrate by the coating, and wetting of the pigment by the resin. The presence of a surfactant can also affect the mechanical, chemical, freezing, and storage stability of the polymers in paints and emulsions. Additionally, surfactants may also affect the water, moisture, heat resistance, and adhesiveness of a polymer film. As such, both ionic and non-ionic surfactants may be used in coating compositions.

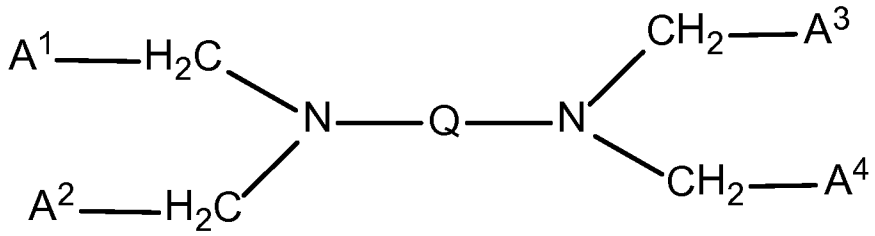
[0002] Gemini surfactants (sometimes referred to as dimeric surfactants) are a new class of surfactants that have two or more hydrophilic groups and two or more hydrophobic groups in the molecules. Typically, gemini surfactants have low critical micelle concentrations, and may be used in lower amounts than conventional surfactants. Gemini surfactants can be ten to a thousand times more surface-active than conventional surfactants with similar but single, hydrophilic and hydrophobic groups in the molecules. Further, gemini surfactants may be anionic, cationic, nonionic or zwitterionic.

[0003] In paint industry, leaching of surfactants, breaking down of emulsion system, and freezing represent major problems in terms of maintaining the quality and durability of the paint. These problems can be overcome by developing new and efficient class of surfactants that are polymeric and self-emulsifying.

SUMMARY

[0004] Disclosed herein are novel gemini surfactants that are non-leachable, have high surfactant efficiency, and form stable emulsions. These gemini surfactants may be used in coating compositions and emulsions to provide hydrophilic, self-cleaning properties when applied on a surface.

[0005] The current disclosure is directed to novel Gemini surfactants. In one embodiment, a compound is of formula I:



(I)

wherein A^1 is -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+[Z-CH_3]_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof;

A^2 is -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof;

A^3 is $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof;

A^4 is $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof;

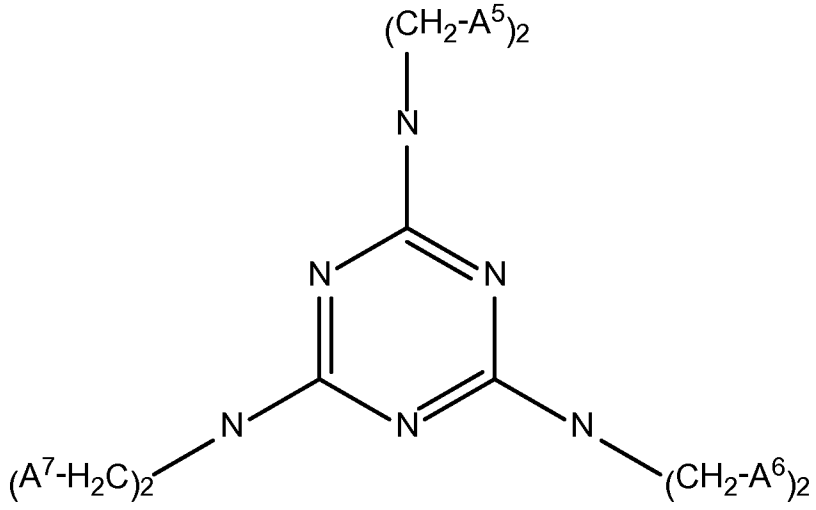
each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent;

Q is –C(=O)-, -CH_2-CH_2-, -CH_2-$(CH_2)_k$-CH_2-, -C(=O)-NH-C(=O)-, or polyurea, where k is an integer from 1 to 10; and

X is Cl, Br, F, I, or OH, and

wherein at least one of A^1, A^2, A^3, and A^4 is hydrophilic, and at least one of A^1, A^2, A^3, and A^4 is hydrophobic.

[0006] In another embodiment, a compound is of formula II:



(II)

wherein each A^5 is, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof;

each A^6 is, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof;

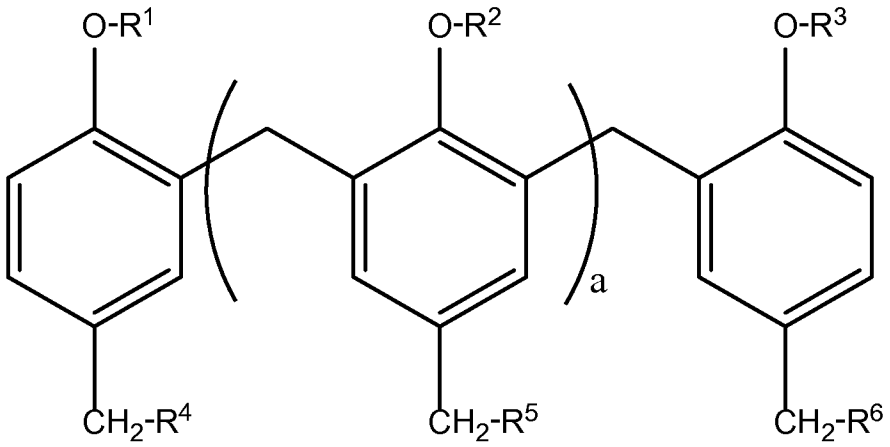
each A^7 is, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^- , -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of A^5, A^6, and A^7 is hydrophilic, and at least one of A^5, A^6, and A^7 is hydrophobic.

[0007] In an additional embodiment, a compound is of formula III:



(III)

wherein

a is an integer from 1 to 10;

R^1 is –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^-.Na^+, or salts thereof;

each R^2 is, independently, $–CH_2$-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, $–CH_2$-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^-.Na^+, or salts thereof;

R^3 is $–CH_2$-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, $–CH_2$-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^-.Na^+, or salts thereof;

R^4 is -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, $–N[CH_2$-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N^+(Z-CH_3)$_3$.X^-, -Z-CH_3, or salts thereof;

each R^5 is, independently, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, $–N[CH_2$-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N^+(Z-CH_3)$_3$.X^-, -Z-CH_3, or salts thereof;

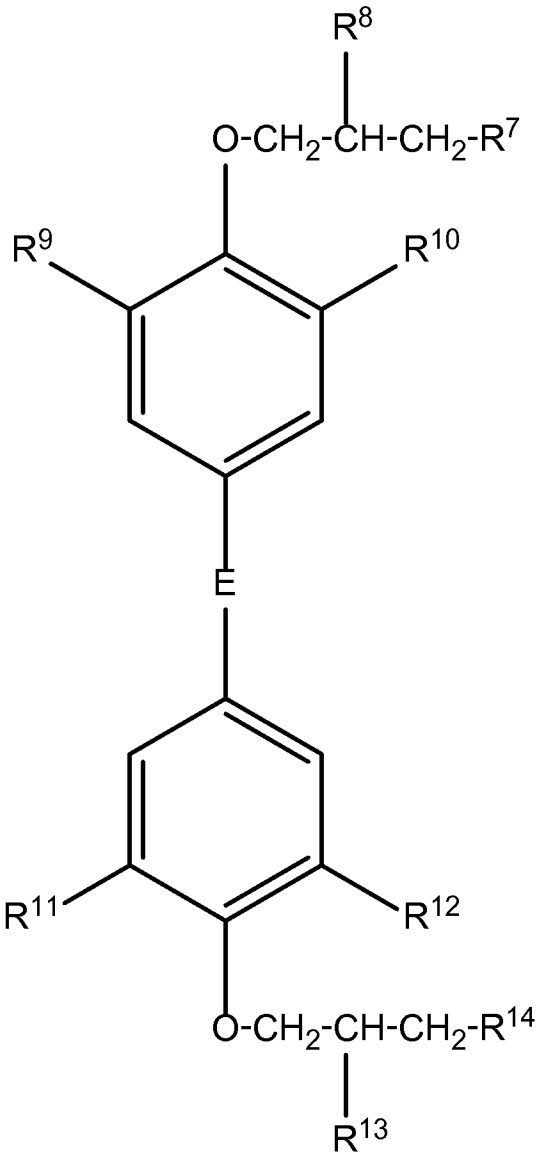
R^6 is -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, $–N[CH_2$-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N^+(Z-CH_3)$_3$.X^-, -Z-CH_3, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophilic, and at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophobic.

[0008] In another embodiment, a compound is of formula IV:



(IV)

wherein

R^7 is $-N(-CH_3)-Z-CH_3$, $-N[CH_2-N^+(CH_3)_3X^-]_2$, $-N^+(CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N-(CH_2-CH_2-COOH)_2$, or salts thereof;

R^8 is –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3$.X^-, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, or salts thereof;

R^9 is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{10} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{11} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{12} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{13} is –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3$.X^-, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, or salts thereof;

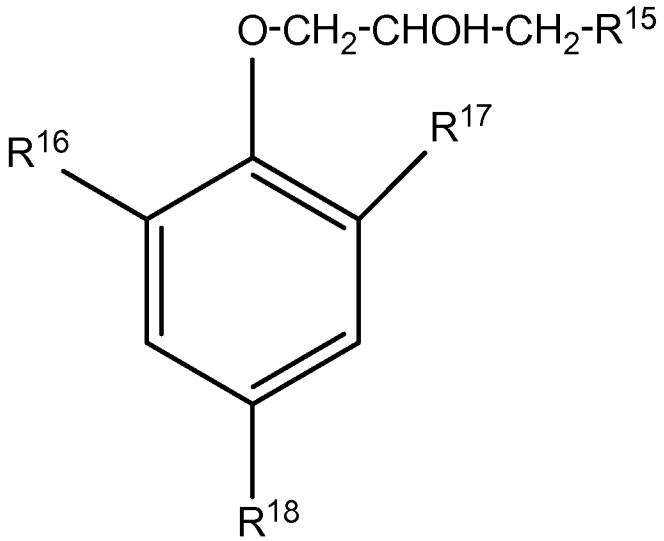
R^{14} is -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3$$X^-$]$_2$, -$N^+$($CH_3$)$_3$.$X^-$, -$N^+H_3$.$X^-$, -N[Z-$CH_3$]$_2$, -NH-$CH_2$-$CH_2$-OH, -N-($CH_2$-$CH_2$-OH)$_2$, -$N^+$($CH_2$-$CH_2$-OH)$_3$.$X^-$, -N-($CH_2$-$CH_2$-COOH)$_2$, or salts thereof;

E is -CH_2-, -$C(CH_3)_2$-, -S-, -$S(=O)_2$-, -S(=O)-, -$CH(CCl_3)$-, -$C(Cl)_2$-, -O-, or -$C(F)_2$-; each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophilic, and at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophobic.

[0009] In a further embodiment, a compound is of formula V:



(V)

wherein

R^{15} is -N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3X^-$]$_2$, -N^+(Z-CH_3)$_3$.X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N-(CH_2-CH_2-COOH)$_2$, or salts thereof;

R^{16} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , -CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)$_2$, or salts thereof;

R^{17} is –H, $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-N^+(CH_2-CH_2-OH)_3$, $-CH_2-O-Z-CH_3$, $-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, or salts thereof;

R^{18} is $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-N^+(CH_2-CH_2-OH)_3$, $-CH_2-O-Z-CH_3$, $-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^{15}, R^{16}, R^{17}, and R^{18} is hydrophilic, and at least one of R^{15}, R^{16}, R^{17}, and R^{18} is hydrophobic.

[0010] In yet another embodiment, a composition may include any one or more of the compounds described herein.

[0011] In a further embodiment, a method of making a compound of formula I may involve contacting any one of urea, biuret, or alkylene diamine with formaldehyde to form a hydroxymethyl compound; and contacting the hydroxymethyl compound with a dimethyl alkyl amine.

[0012] In an additional embodiment, a method of making a compound of formula II may involve contacting melamine with formaldehyde to form a hydroxymethyl melamine derivative; contacting the hydroxymethyl melamine derivative with diethanolamine to form a diethanol melamine derivative; and contacting the diethanol melamine derivative with an alkyl halide.

[0013] In a further embodiment, a method of making a compound of formula III may involve contacting novolac with epichlorohydrin to form a novolac-chlorohydrin derivative; contacting the novolac-chlorohydrin derivative with any one of diethanolamine or triethylamine to form a novolac derivative; and contacting the novolac derivative with an alkyl chloride.

[0014] In another embodiment, a method of making a compound of formula IV may involve contacting a bisphenol compound with epichlorohydrin and formaldehyde to form a tetramethylol bisphenol derivative; and contacting the tetramethylol bisphenol derivative with any one of the following: a mixture of trimethylamine and N,N,N,-trialkyl amine, a mixture of diethanol amine and N,N,N,-trialkyl amine, and a mixture of disodium propionate amine and N,N,N,-trialkyl amine.

[0015] In yet an another embodiment, a method of making a compound of formula V may involve contacting a resol with epichlorohydrin to form a resol-chlorohydrin derivation; and contacting the resol-chlorohydrin derivative with any one of the following: a mixture of triethylamine and N,N,N,-trialkyl amine, a mixture of diethanol amine and N,N,N,-trialkyl amine, a mixture of disodium propionate amine and N,N,N,-trialkyl amine.

[0016] In a further embodiment, a method of coating a substrate may involve applying a coating composition to the substrate, wherein the coating composition comprises one or more compounds of formula I-V.

DETAILED DESCRIPTION

[0017] This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[0018] "Alkyl" means a saturated hydrocarbon group which is straight-chained or branched. An alkyl group can contain from 1 to 20 carbon atoms, from 2 to 20 carbon atoms, from 1 to 10 carbon atoms, from 2 to 10 carbon atoms, from 1 to 8 carbon atoms, from 2 to 8 carbon atoms, from 1 to 6 carbon atoms, from 2 to 6 carbon atoms, from 1 to 4 carbon atoms, from 2 to 4 carbon atoms, from 1 to 3 carbon atoms, or 2 or 3 carbon atoms. Examples of alkyl groups include, but are not limited to, methyl (Me), ethyl (Et), propyl (for example, n-propyl and isopropyl), butyl (for example, n-butyl, t-butyl, isobutyl), pentyl (for example, n-pentyl, isopentyl, neopentyl), hexyl, isohexyl, heptyl, 4,4 dimethylpentyl, octyl, 2,2,4-trimethylpentyl, nonyl, decyl, undecyl, dodecyl, 2-methyl-1-propyl, 2-methyl-2-propyl, 2-methyl-1-butyl, 3-methyl-1-butyl, 2-methyl-3-butyl, 2-methyl-1-pentyl, 2,2-dimethyl-1-propyl, 3-methyl-1-pentyl, 4-methyl-1-pentyl, 2-methyl-2-pentyl, 3-methyl-2-pentyl, 4-methyl-2-pentyl, 2,2-dimethyl-1-butyl, 3,3-dimethyl-1-butyl, 2-ethyl-1-butyl, and the like.

[0019] "Substituted alkyl" refers to an alkyl as just described in which one or more hydrogen atoms attached to carbon of the alkyl is replaced by another group, such as halogen, aryl, substituted aryl, cycloalkyl, substituted cycloalkyl, and combinations thereof. Suitable substituted alkyls include, for example, benzyl and trifluoromethyl.

[0020] "Alkylene" refers to a bivalent alkyl moiety having the general formula $-(CH_2)_n-$, where n is from about 1 to about 25, about 1 to about 20, or about 4 to about 20. By bivalent, it is meant that the group has two open sites each of which bonds to another group. Non-limiting examples include methylene, ethylene, trimethylene, pentamethylene, and hexamethylene. Alkylene groups can be substituted or unsubstituted, linear or branched bivalent alkyl groups.

[0021] "Alkenyl" means a straight or branched alkyl group having one or more double carbon-carbon bonds and 2-20 carbon atoms, including, but not limited to, ethenyl, 1-propenyl, 2-propenyl, 2-methyl-1-propenyl, 1-butenyl, 2-butenyl, and the like. In some

embodiments, the alkenyl chain is from 2 to 10 carbon atoms in length, from 2 to 8 carbon atoms in length, from 2 to 6 carbon atoms in length, or from 2 to 4 carbon atoms in length.

[0022] "Alkenylene" refers to a divalent alkenyl moiety, meaning the alkenyl moiety is attached to the rest of the molecule by a divalent linkage.

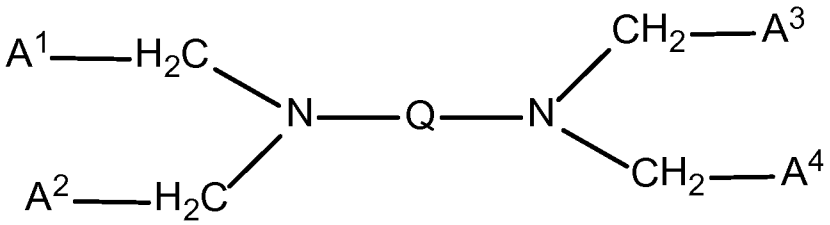
[0023] "Alkynyl" means a straight or branched alkyl group having one or more triple carbon-carbon bonds and 2-20 carbon atoms, including, but not limited to, acetylene, 1-propylene, 2-propylene, and the like. In some embodiments, the alkynyl chain is 2 to 10 carbon atoms in length, from 2 to 8 carbon atoms in length, from 2 to 6 carbon atoms in length, or from 2 to 4 carbon atoms in length.

[0024] "Alkynylene" refers to a divalent alkynyl moiety, meaning the alkynyl moiety is attached to the rest of the molecule by a divalent linkage.

[0025] "Arylene" means a bivalent aryl group that links one group to another group in a molecule. Arylene groups may be substituted or unsubstituted.

[0026] Disclosed herein are gemini surfactants, and methods of making such surfactants. These gemini surfactants may be used in various applications, such as in coating compositions, emulsions, demulsifying agents, phase transfer catalysts, dispersants, and defoamers.

[0027] In some embodiments, a compound is of formula I:



(I)

wherein A^1 may be -H, $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, $-N^+[Z\text{-}CH_3]_3.X^-$, $-O\text{-}C(=O)\text{-}COO^-.Na^+$, $-N^+(\text{-}CH_3)_2\text{-}Z\text{-}CH_3.X^-$, or salts thereof. In some embodiments, A^1 may be -H, $–N[CH_2\text{-}N^+(Z\text{-}$

$CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, or $-O-Z-CH_3$. In some embodiments, A^1 may be -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, or $-NH-CH_2-CH_2-OH$.

[0028] In some embodiments, A^2 may be -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof. In some embodiments, A^2 may be -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, or $-O-Z-CH_3$. In some embodiments, A^2 may be -H, $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, or $-NH-CH_2-CH_2-OH$.

[0029] In some embodiments, A^3 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof. In some embodiments, A^3 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$,or $-O-Z-CH_3$. In some embodiments, A^3 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, or $-NH-CH_2-CH_2-OH$.

[0030] In some embodiments, A^4 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, $-N^+(Z-CH_3)_3.X^-$, $-O-C(=O)-COO^-.Na^+$, $-N^+(-CH_3)_2-Z-CH_3.X^-$, or salts thereof. In some embodiments, A^4 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N^+(CH_2-CH_2-OH)_3.X^-$, or $-O-Z-CH_3$. In some embodiments, A^4 may be $-N[CH_2-N^+(Z-CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, or $-NH-CH_2-CH_2-OH$.

[0031] In some embodiments, each Z may be, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent.

[0032] In some embodiments, Q may be –C(=O)-, -CH_2-CH_2-, -CH_2-$(CH_2)_k$-CH_2-, -C(=O)-NH-C(=O)-, or polyurea, where k is an integer from 1 to 10.

[0033] In some embodiments, X may be Cl, Br, F, I, or OH. In some embodiments, in the compound of formula I disclosed herein, at least one of A^1, A^2, A^3, and A^4 may be hydrophilic, and at least one of A^1, A^2, A^3, and A^4 may be hydrophobic.

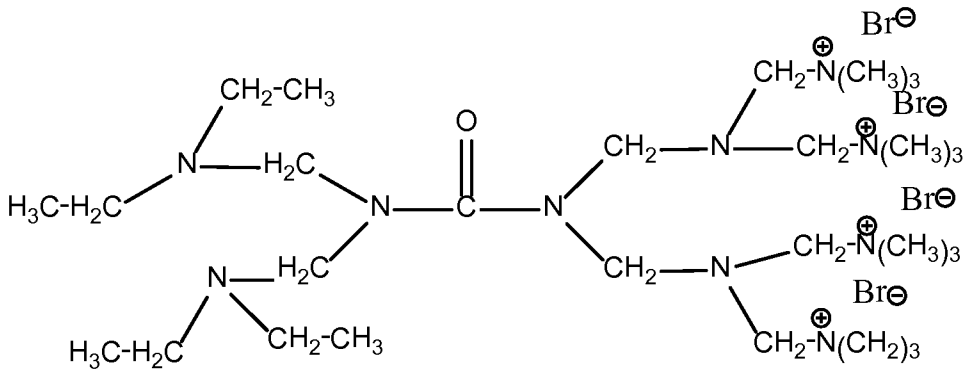
[0034] In some embodiments, the compound of formula I may have the following substitutions at each of, independently, A^1, A^2, A^3, A^4, and Q as shown in Table 1:

TABLE 1

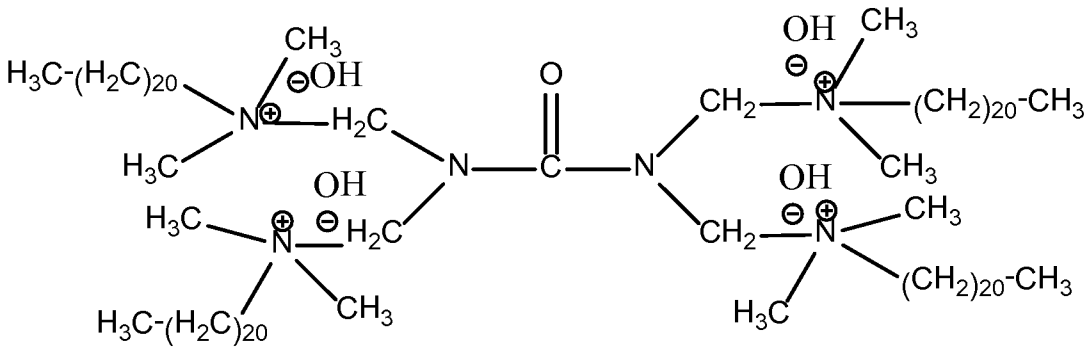
Q	A^1	A^2	A^3	A^4
–C(=O)-, -CH_2-CH_2-, -CH_2-$(CH_2)_k$-CH_2- , -C(=O)-NH-C(=O)-, or polyurea, where k is an integer from 1 to 10.	-H, –N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+[Z-CH_3]$_3$.X^-, -O-C(=O)-COO^-.Na^+, -N^+(-CH_3)$_2$-Z-CH_3.X^-, or salts thereof;	-H, –N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, -N^+(-CH_3)$_2$-Z-CH_3.X^-, or salts thereof;	–N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, -N^+(-CH_3)$_2$-Z-CH_3.X^-, or salts thereof;	–N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, -N^+(-CH_3)$_2$-Z-CH_3.X^-, or salts thereof;
–C(=O)-, -CH_2-CH_2-, -CH_2-$(CH_2)_k$-CH_2- , -C(=O)-NH-C(=O)-, or polyurea, where k is an integer from 1 to 10.	-H, –N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.	-H, –N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.	–N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.	–N[CH_2-N^+(Z-CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.
–C(=O)- or -CH_2-$(CH_2)_k$-CH_2-	-N[Z-CH_3]$_2$ or -O-Z-CH_3	-N[Z-CH_3]$_2$ or -O-Z-CH_3	–N[CH_2-N^+(CH_3)$_3$$Br^-$]$_2$ or -N^+(Z-CH_3)$_3$.Br^-	–N[CH_2-N^+(CH_3)$_3$$Br^-$]$_2$ or -N^+(Z-CH_3)$_3$.Br^-
–C(=O)-	-N[Z-CH_3]$_2$	-N[Z-CH_3]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$

–C(=O)-	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3
–C(=O)-	-O-C(=O)-COOH	-O-Z-CH_3	-O-C(=O)-COOH	-O-Z-CH_3
–C(=O)-	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3
–C(=O)-	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3
-C(=O)-NH-C(=O)-	-N[Z-CH_3]$_2$	-N[Z-CH_3]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$
-C(=O)-NH-C(=O)-	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3
-C(=O)-NH-C(=O)-	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3
-C(=O)-NH-C(=O)-	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3
-CH_2-(CH_2)$_k$-CH_2-	-N[Z-CH_3]$_2$	-N[Z-CH_3]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$	–N[CH_2-N^+(CH_3)3.Br^-]$_2$
-CH_2-(CH_2)$_k$-CH_2-	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3	-O-C(=O)-COO^- .Na^+	-O-Z-CH_3
-CH_2-(CH_2)$_k$-CH_2-	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3	–N[CH_2-N^+(Z-CH_3)$_3$.OH^-]$_2$	-O-Z-CH_3
-CH_2-(CH_2)$_k$-CH_2-	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3	-N^+(Z-CH_3)$_3$.Br^-	-O-Z-CH_3
–C(=O)-	-N^+(-CH_3)$_2$-Z-CH_3.OH^-	-N^+(-CH_3)$_2$-Z-CH_3.OH^-	-N^+(-CH_3)$_2$-Z-CH_3.OH^-	-N^+(-CH_3)$_2$-Z-CH_3.OH^-

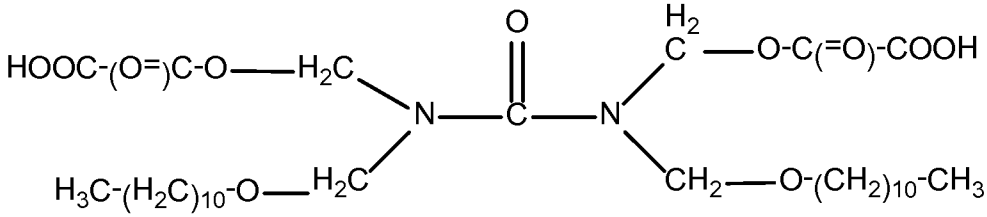
[0035] Examples of compounds represented by formula I include, but are not limited to, the following compounds:



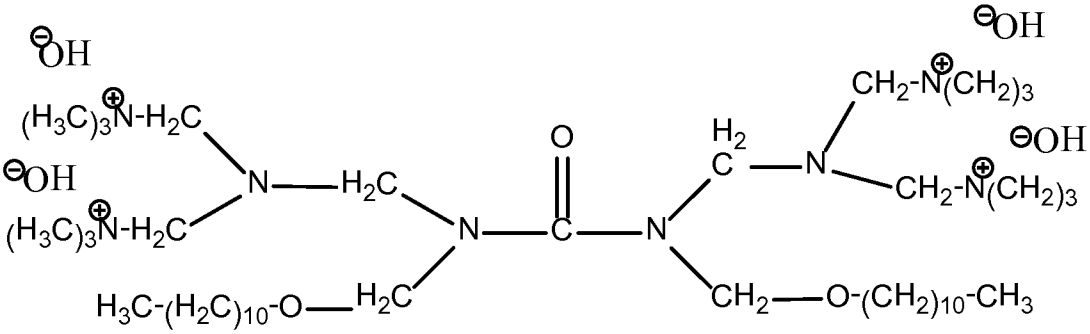
compound 1



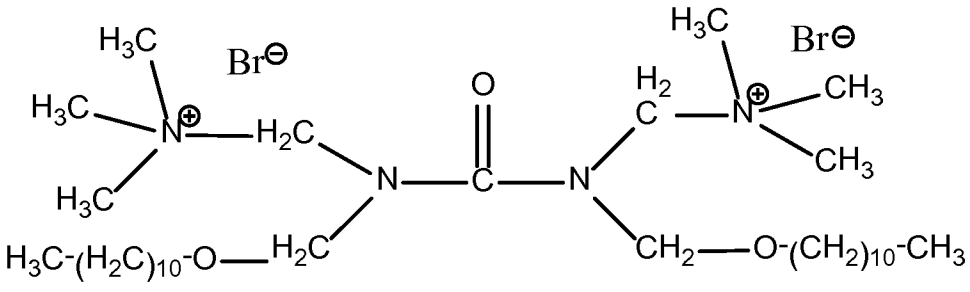
compound 2



compound 3

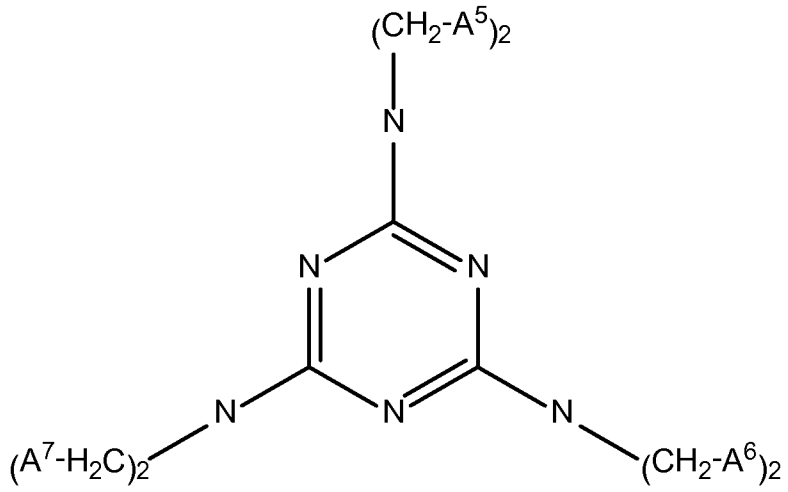


compound 4



compound 5

[0036] In some embodiments, a compound is of formula II:



(II)

wherein each A^5 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof. In some embodiments, each A^5 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, each A^5 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, or –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$.

[0037] In some embodiments, each A^6 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof. In some embodiments, each A^6 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-

CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3. In some embodiments, each A^6 may be, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH.

[0038] In some embodiments, each A^7 may be, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, or salts thereof. In some embodiments, each A^7 may be, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3. In some embodiments, each A^7 may be, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH.

[0039] In some embodiments, each Z may be, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent.

[0040] In some embodiments, X may be Cl, Br, F, I, or OH.

[0041] In some embodiments, in compound of formula II, at least one of A^5, A^6, and A^7 may be hydrophilic, and at least one of A^5, A^6, and A^7 may be hydrophobic.

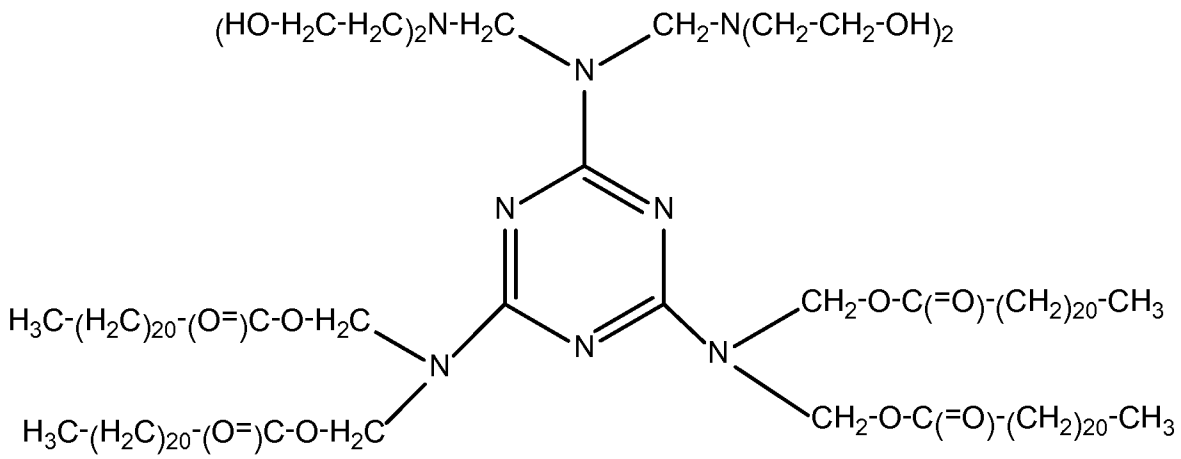
[0042] In some embodiments, the compound of formula II may have the following substitutions at each of, independently, A^5, A^6, and A^7 as shown in Table 2:

TABLE 2

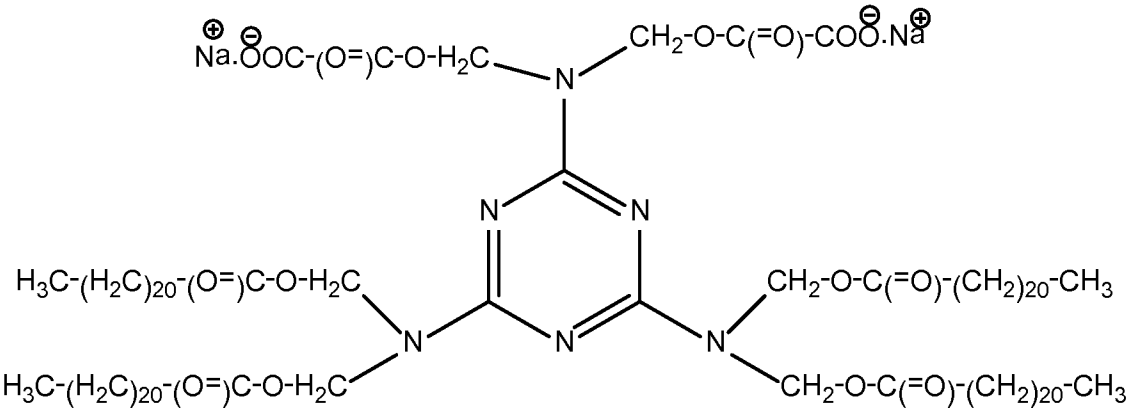
A^5	A^6	A^7
-H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$ or salts thereof.	-H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof.	-O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -N^+(Z-CH_3)$_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof;
-H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH.	-H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH.	-O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH.
-O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, or -O-Z-CH_3.	-O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, or -O-Z-CH_3.	-O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, or -O-Z-CH_3.
-$N^+H_3Br^-$ or –N[CH_2-$N^+(CH_3)_3Br^-$]$_2$	-N[Z-CH_3]$_2$ or -O-Z-CH_3	-N[Z-CH_3]$_2$ or -O-Z-CH_3
-N^+(Z-CH_3)$_3.X^-$ or –SO_3H	-O-C(=O)-Z-CH_3 or -N(-CH_3)-Z-CH_3	-O-C(=O)-Z-CH_3 or -N(-CH_3)-Z-CH_3
–N(CH_2-CH_2-OH)$_2$	-O-C(=O)-Z-CH_3	-O-C(=O)-Z-CH_3
-O-C(=O)-$COO^-.Na^+$	-O-C(=O)-Z-CH_3	-O-C(=O)-Z-CH_3
-O-$SO^-_3.Na^+$	-O-C(=O)-Z-CH_3	-O-C(=O)-Z-CH_3
-N^+(Z-CH_3)$_3.OH^-$	-N^+(Z-CH_3)$_3.OH^-$	-N^+(Z-CH_3)$_3.OH^-$

-O-PO^{2-}_3,2Na^+	-O-C(=O)-Z-CH_3	-O-C(=O)-Z-CH_3

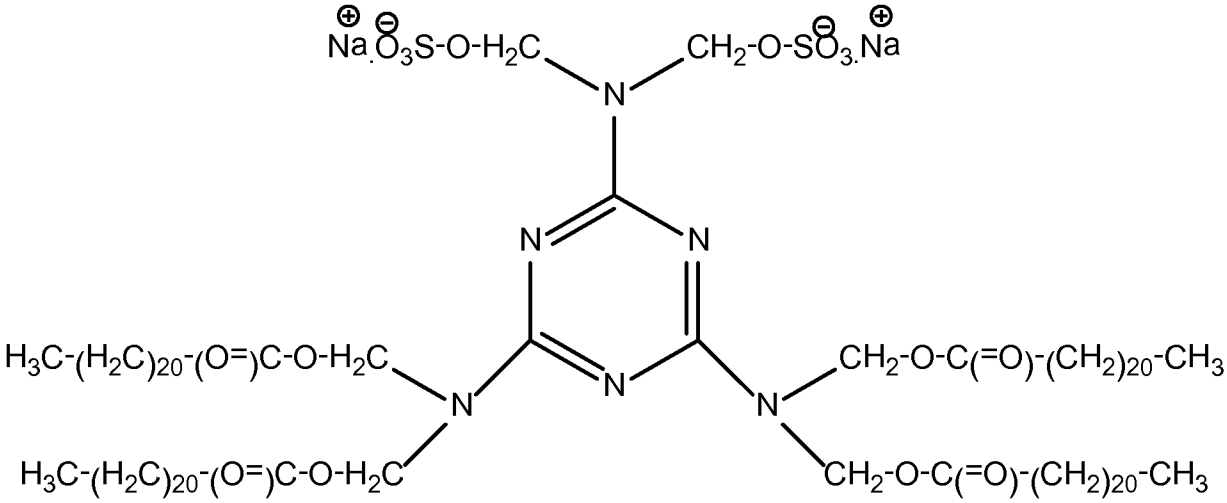
[0043] Examples of compounds represented by formula II include, but are not limited to, the following compounds:



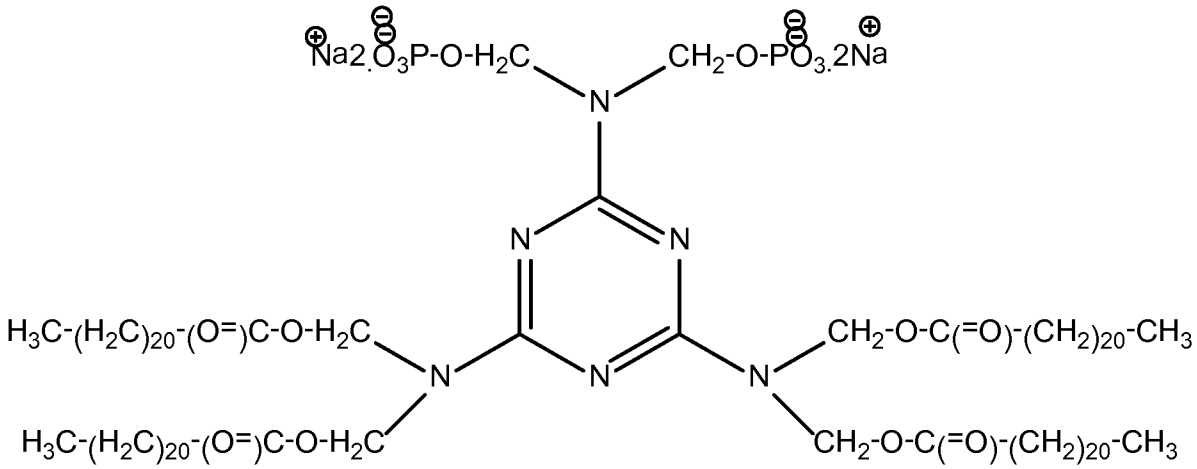
compound 6



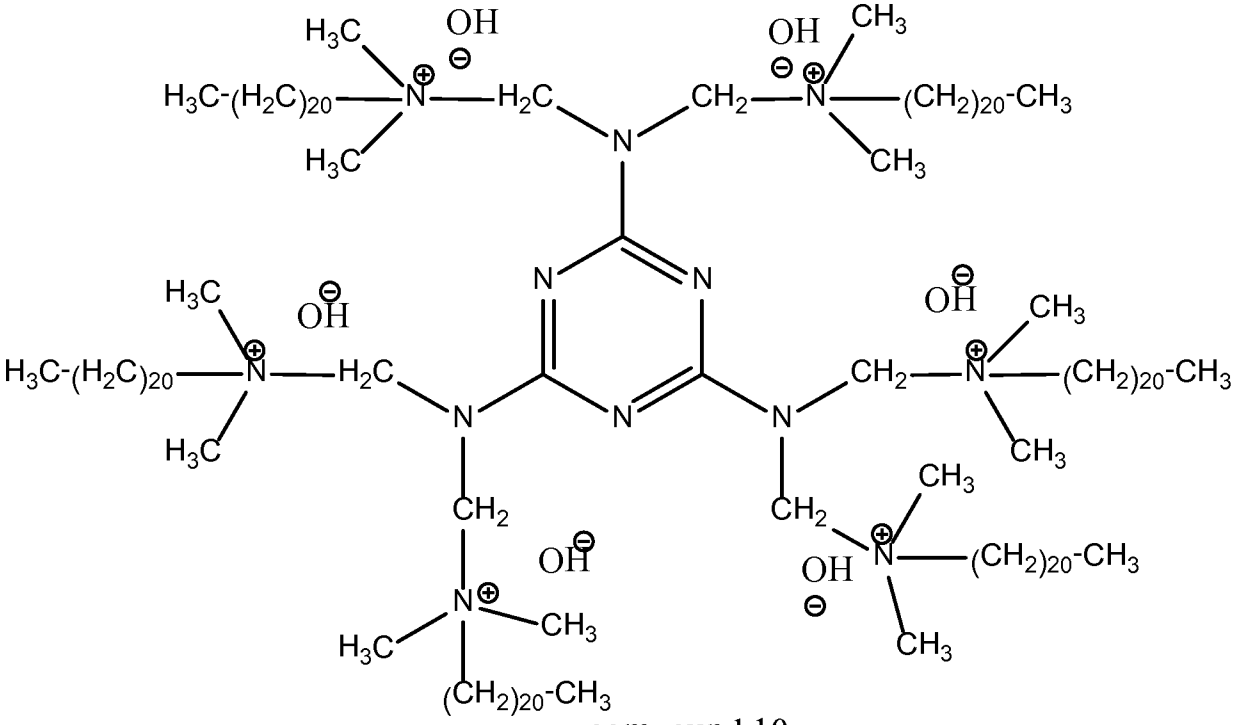
compound 7



compound 8

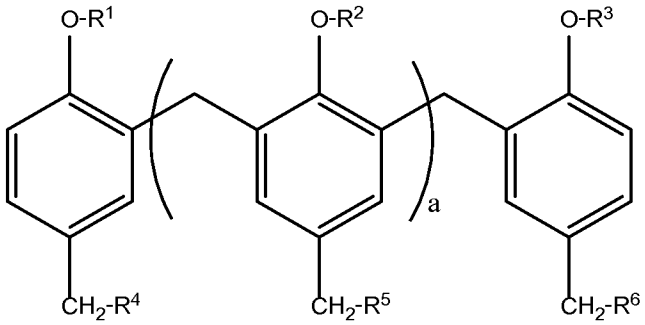


compound 9



compound 10

[0044] In some embodiments, a compound is of formula III:



(III)

wherein a is an integer from 1 to 10. In some embodiments, R^1 may be $–CH_2-N(-CH_3)-Z-CH_3$, $-C(=O)-CH_2-CH_2-COOH$, $-C(=O)-CH_2-COOH$, $-SO_3H$, $-PO_3H_2$, $–CH_2-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$, $-CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-COO^-.Na^+$, or salts thereof. In some embodiments, R^1 may be $–CH_2-N(-CH_3)-Z-CH_3$, -

C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, or -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^1 may be –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, or -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$.

[0045] In some embodiments, each R^2 may be, independently, –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3.X^-$, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3.X^-$, -CH_2-$COO^-.Na^+$, or salts thereof. In some embodiments, each R^2 may be, independently, –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, or -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$. In some embodiments, each R^2 may be, independently, –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$

[0046] In some embodiments, R^3 may be–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3.X^-$, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3.X^-$, -CH_2-$COO^-.Na^+$, or salts thereof. In some embodiments, R^3 may be –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-

$N^+(CH_3)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$, $-CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH$, or $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$. In some embodiments, R^3 may be $–CH_2-N(-CH_3)-Z-CH_3$, $-C(=O)-CH_2-CH_2-COOH$, $-C(=O)-CH_2-COOH$, $-SO_3H$, $-PO_3H_2$, $–CH_2-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$, or $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$.

[0047] In some embodiments, R^4 may be $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N^+(Z-CH_3)_3.X^-$, $-Z-CH_3$, or salts thereof. In some embodiments, R^4 may be $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, or $-N-(CH_2-CH_2-OH)_2$. In some embodiments, R^4 may be $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, or $-N^+H_3.X^-$.

[0048] In some embodiments, each R^5 may be, independently, $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N^+(Z-CH_3)_3.X^-$, $-Z-CH_3$, or salts thereof. In some embodiments, each R^5 may be, independently, $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, or $-N-(CH_2-CH_2-OH)_2$. In some embodiments, each R^5 may be, independently, $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, or $-N^+H_3.X^-$.

[0049] In some embodiments, R^6 may be $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N^+(Z-CH_3)_3.X^-$, $-Z-CH_3$, or salts thereof. In some embodiments, R^6 may be $-N(-CH_3)-Z-CH_3$, $-O-$

C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^6 may be -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, or -$N^+H_3.X^-$.

[0050] In some embodiments, each Z may be, independently, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent.

[0051] In some embodiments, X may be Cl, Br, F, I, or OH.

[0052] In some embodiments, in compound of formula III, at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophilic, and at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophobic.

[0053] In some embodiments, the compound of formula III may have substitutions at each of, independently, R^1, R^2, R^3, R^4, R^5, and R^6 as shown in Table 3:

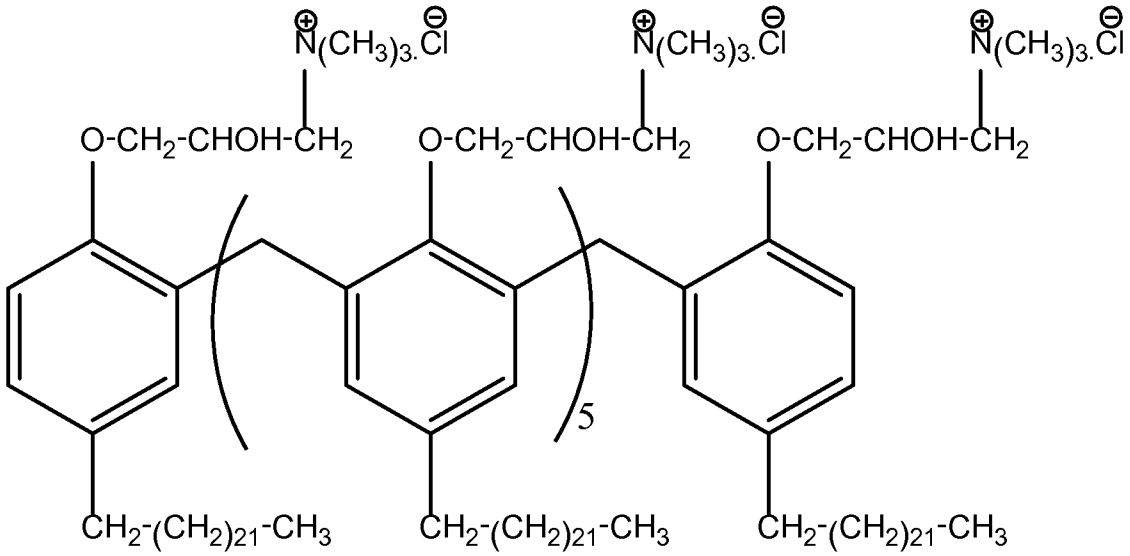
TABLE 3

R^1	R^2	R^3	R^4	R^5	R^6
–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-(CH_2-	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH, -CH_2-CH(-OH)-CH_2-N-	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -N^+(Z-CH_3)$_3.X^-$,	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -N^+(Z-CH_3)$_3$. X^-,	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -N^+(Z-CH_3)$_3$. X^-,

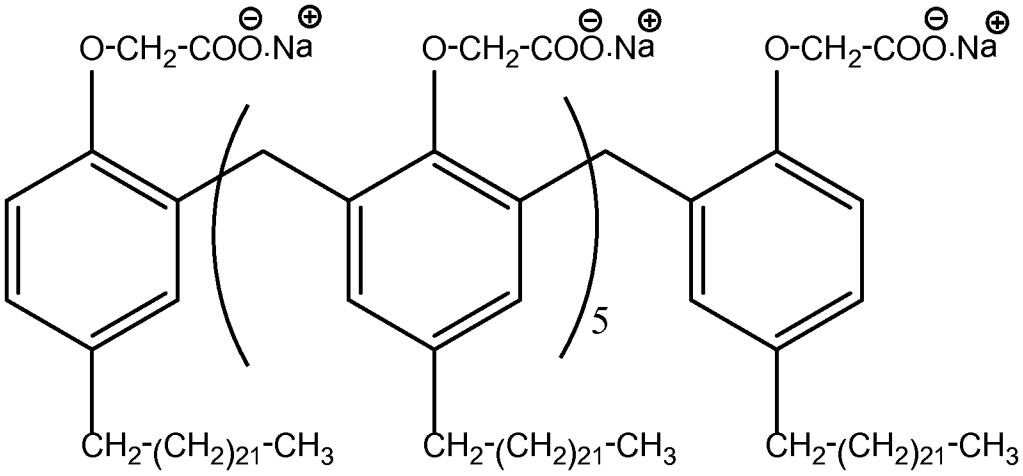
CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^- .Na^+, or salts thereof;	(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^- .Na^+, or salts thereof;	(CH_2-CH_2-OH)$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)$_3$.X^-, -CH_2-COO^- .Na^+, or salts thereof;	-Z-CH_3, or salts thereof;	-Z-CH_3, or salts thereof;	-Z-CH_3, or salts thereof;
–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$. X^-, -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$, or -CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$. X^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$. X^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, or -NH-CH_2-CH_2-OH,
–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$. Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$. Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -N^+H_3.Br^-, or -N[Z-CH_3]$_2$.	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -N^+H_3.Br^-, or -N[Z-CH_3]$_2$.	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -N^+H_3.Br^-, or -N[Z-CH_3]$_2$.
–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, or -C(=O)-CH_2-COOH	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, or -C(=O)-CH_2-COOH	–CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, or -C(=O)-CH_2-COOH	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, or -O-C(=O)-CH_2-COOH	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, or -O-C(=O)-CH_2-COOH	-N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, or -O-C(=O)-CH_2-COOH
–CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$	–CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$	–CH_2-N[CH_2-N^+(CH_3)$_3$.X^-]$_2$	-N(-CH_3)-Z-CH_3	-N(-CH_3)-Z-CH_3	-N(-CH_3)-Z-CH_3

or $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$	or $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$	or $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$	or $-N[Z-CH_3]_2$	or $-N[Z-CH_3]_2$	or $-N[Z-CH_3]_2$
$-CH_2-COO^-.Na^+$	$-CH_2-COO^-.Na^+$	$-CH_2-COO^-.Na^+$	$-N[Z-CH_3]_2$	$-N[Z-CH_3]_2$	$-N[Z-CH_3]_2$
$-CH_2-COO^-.Na^+$	$-CH_2-COO^-.Na^+$	$-CH_2-COO^-.Na^+$	$-Z-CH_3$	$-Z-CH_3$	$-Z-CH_3$
$-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.Cl^-$	$-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.Cl^-$	$-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.Cl^-$	$-Z-CH_3$	$-Z-CH_3$	$-Z-CH_3$
$-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$	$-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$	$-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$	$-Z-CH_3$	$-Z-CH_3$	$-Z-CH_3$

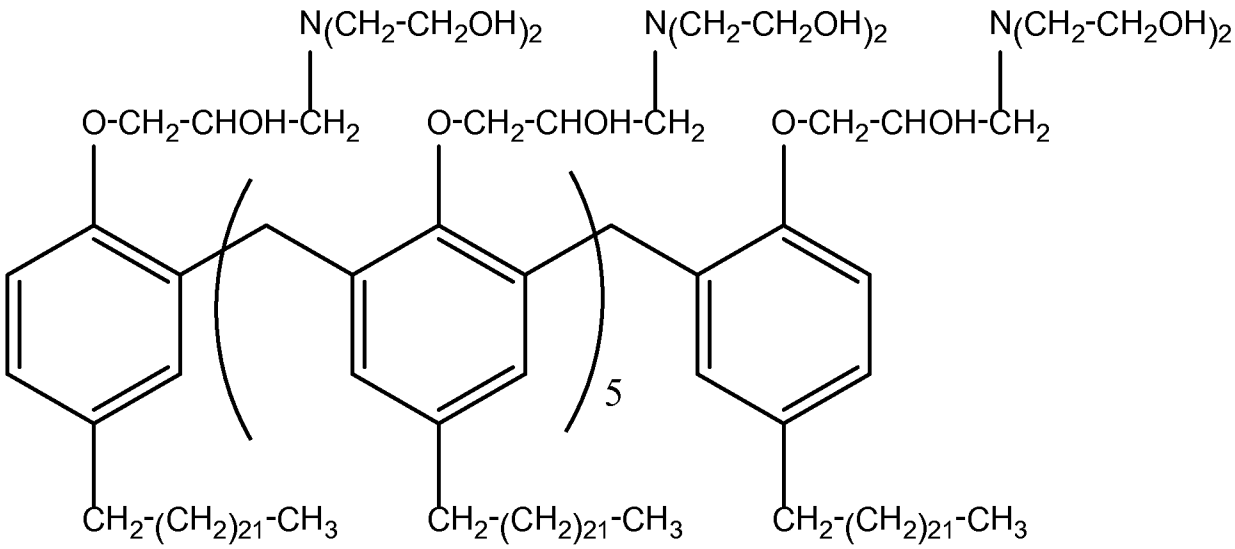
[0054] Examples of compounds represented by formula III include, but are not limited to, the following compounds:



compound 11

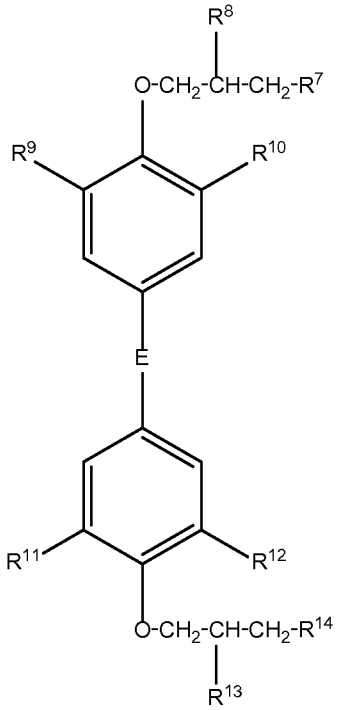


compound 12



compound 13

[0055] In some embodiments, a compound is of formula IV:



(IV)

wherein R^7 may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(CH_3)$_3$.X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N-(CH_2-CH_2-COOH)$_2$, or salts thereof. In some embodiments, R^7 may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(CH_3)$_3$.X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^7 may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(CH_3)$_3$.X^-, or -N^+H_3.X^-, -N[Z-CH_3]$_2$.

[0056] In some embodiments, R^8 may be –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3$.X^-, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, or salts thereof. In some embodiments, R^8 may be –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3$.X^-, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^8 may be –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-

CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3.X^-$]$_2$, or -$N^+H_3.X^-$.

[0057] In some embodiments, R^9 may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^-, or salts thereof. In some embodiments, R^9 may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, or -CH_2-N^+(CH_2-CH_2-OH)$_3$. In some embodiments, R^9 may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, or -CH_2-NH-CH_2-CH_2-OH.

[0058] In some embodiments, R^{10} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^-, or salts thereof. In some embodiments, R^{10} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^{10} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, or -CH_2-N[Z-CH_3]$_2$.

[0059] In some embodiments, R^{11} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^-, or salts thereof. In some embodiments, R^{11} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, or -CH_2-

$N^+(CH_2\text{-}CH_2\text{-}OH)_3$. In some embodiments, R^{11} may be –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, or $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$.

[0060] In some embodiments, R^{12} may be –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3$, $-CH_2\text{-}O\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-$, or salts thereof. In some embodiments, R^{12} may be –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, or $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3$. In some embodiments, R^{12} may be –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, or $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$.

[0061] In some embodiments, R^{13} may be –OH, $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-N[CH_2\text{-}N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, or salts thereof. In some embodiments, R^{13} may be –OH, $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-N[CH_2\text{-}N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, or $-N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$. In some embodiments, R^{13} may be –OH, $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-N[CH_2\text{-}N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, or $-N[Z\text{-}CH_3]_2$.

[0062] In some embodiments, R^{14} may be $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-N[CH_2\text{-}N^+(CH_3)_3X^-]_2$, $-N^+(CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-N\text{-}(CH_2\text{-}CH_2\text{-}COOH)_2$, or salts thereof. In some embodiments, R^{14} may be $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-N[CH_2\text{-}N^+(CH_3)_3X^-]_2$, $-N^+(CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}$

CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^{14} may be -N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3X^-$]$_2$, -$N^+(CH_3)_3.X^-$, or -$N^+H_3.X^-$, -N[Z-CH_3]$_2$.

[0063] In some embodiments, E may be -CH_2-, -$C(CH_3)_2$-, -S-, -S(=O)$_2$-, -S(=O)-, -$CH(CCl_3)$-, -$C(Cl)_2$-, -O-, or -$C(F)_2$-.

[0064] In some embodiments, each Z may be, independently, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent.

[0065] In some embodiments, X may be Cl, Br, F, I, or OH.

[0066] In some embodiments, in compound of formula IV, at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophilic, and at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophobic.

[0067] In some embodiments, the compound of formula IV may have substitutions at each of, independently, R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} as shown in Table 4:

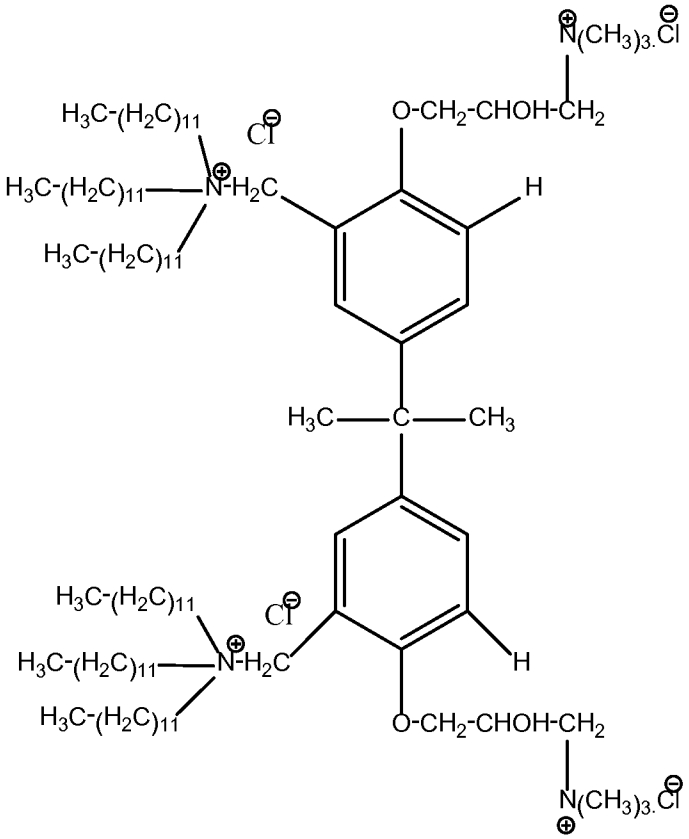
TABLE 4

E	R^7	R^8	R^9	R^{10}	R^{11}	R^{12}	R^{13}	R^{14}
-CH_2-, -C (CH_3)$_2$-, -S-, -S(=O)$_2$-, -S(=O)-, -$CH(CCl_3)$-, -$C(Cl)_2$-, -O-, or -$C(F)_2$-.	-N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3$ X^-]$_2$, -N^+ $(CH_3)_3$. X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-	–OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3$. X^-]$_2$, -N^+H_3. X^-,	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-	–OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3$. X^-]$_2$,	-N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3$ X^-]$_2$, -N^+ $(CH_3)_3$. X^-, -N^+H_3. X^- , -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$,

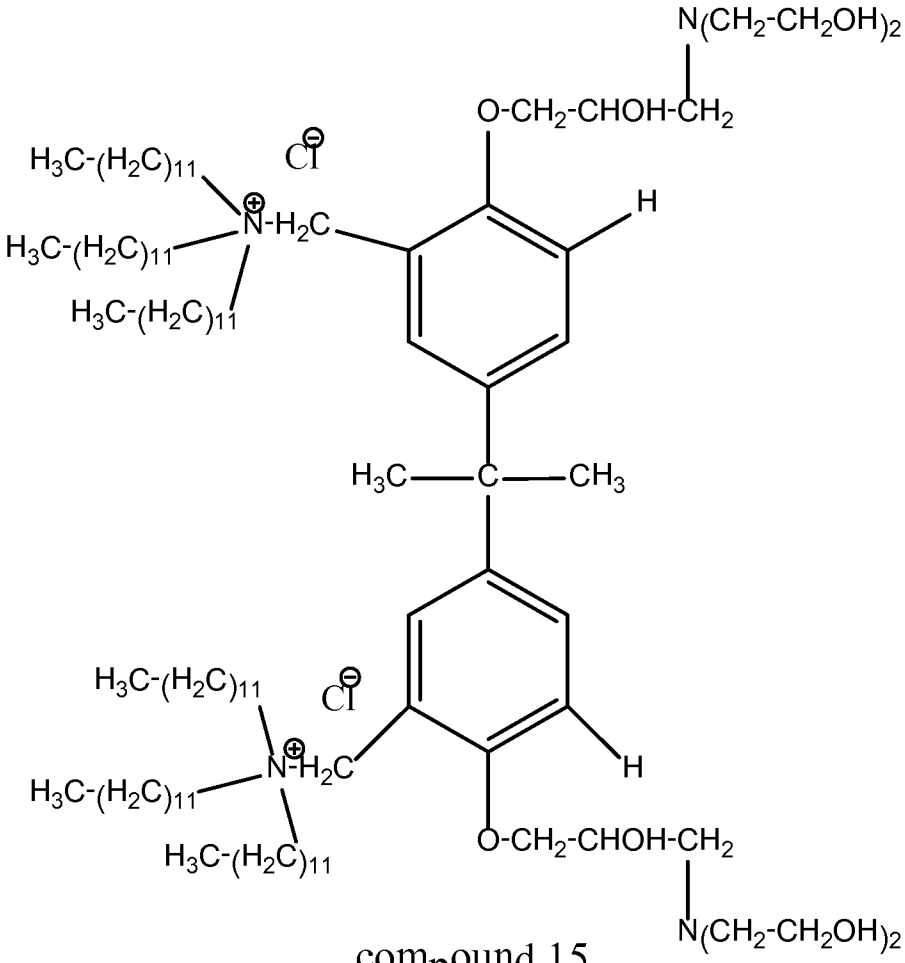
	CH_2-$OH)_3.X^-$, -N-(CH_2-CH_2-$COOH)_2$, or salts thereof;	-N[Z-$CH_3]_2$, -N^+(Z-$CH_3)_3.X^-$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-$OH)_2$, -N^+(CH_2-CH_2-$OH)_3.X^-$, -O-Z-CH_3, or salts thereof	$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-$OH)_2$, -CH_2-N^+(CH_2-CH_2-$OH)_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-$CH_3)_3.X^-$, or salts thereof	$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-$OH)_2$, -CH_2-N^+(CH_2-CH_2-$OH)_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-$CH_3)_3.X^-$, or salts thereof	N[Z-$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-$OH)_2$, -CH_2-N^+(CH_2-CH_2-$OH)_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-$CH_3)_3.X^-$, or salts thereof	$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-$OH)_2$, -CH_2-N^+(CH_2-CH_2-$OH)_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-$CH_3)_3.X^-$, or salts thereof	-$N^+H_3.X^-$, -N[Z-$CH_3]_2$, -N^+(Z-$CH_3)_3.X^-$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-$OH)_2$, -N^+(CH_2-CH_2-$OH)_3.X^-$, -O-Z-CH_3, or salts thereof	-N^+(CH_2-CH_2-$OH)_3.X^-$, -N-(CH_2-CH_2-$COOH)_2$, or salts thereof
-CH_2-, -C ($CH_3)_2$-, -S-, -S(=O)$_2$-, -S(=O)-, -CH(CCl_3)-, -C($Cl)_2$-, -O-, or -C($F)_2$-.	-N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3$ $X^-]_2$, -N^+ ($CH_3)_3$. X^-, -$N^+H_3.X^-$, -N[Z-$CH_3]_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-$OH)_2$	–OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3$. $X^-]_2$, -$N^+H_3.X^-$, -N[Z-$CH_3]_2$, -N^+(Z-$CH_3)_3.X^-$, or -NH-CH_2-CH_2-OH	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-$OH)_2$	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-$OH)_2$	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-$CH_3]_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-$OH)_2$	–OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3$. $X^-]_2$, -$N^+H_3.X^-$, -N[Z-$CH_3]_2$, -N^+(Z-$CH_3)_3.X^-$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-$OH)_2$	-N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3$ $X^-]_2$, -N^+ ($CH_3)_3$. X^-, -N^+H_3. X^-, -N[Z-$CH_3]_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-$OH)_2$
-C-($CH_3)_2$	-N^+ ($CH_3)_3$. Cl^-	-OH	-CH_2-N^+(Z-$CH_3)_3$. Cl^-	-H	-CH_2-N^+(Z-$CH_3)_3$. Cl^-	-H	-OH	-N^+ ($CH_3)_3$. Cl^-
-C-($CH_3)_2$	–N(CH_2-	-OH	-CH_2-	-H	-CH_2-	-H	-OH	–N(CH_2-

	CH_2-$OH)_2$		N^+(Z-$CH_3)_3$. Cl^-		N^+(Z-$CH_3)_3$. Cl^-			CH_2-$OH)_2$
-C-$(CH_3)_2$	–N(CH_2-CH_2-COO^- .$Na^+)_2$	-OH	-CH_2-N^+(Z-$CH_3)_3$.X^-	-H	-CH_2-N^+(Z-$CH_3)_3$.X^-	-H	-OH	–N(CH_2-CH_2-COO^- .$Na^+)_2$
-C-$(CH_3)_2$	-N^+ $(CH_3)_3$. Cl^-	-O-C(=O)-Z-CH_3	-H	-H	-H	-H	-O-C(=O)-Z-CH_3	-N^+ $(CH_3)_3$. Cl^-
-C-$(CH_3)_2$	–N(CH_2-CH_2-$OH)_2$	-N^+(Z-$CH_3)_3$.X^-	-H	-H	-H	-H	-N^+(Z-$CH_3)_3$.X^-	–N(CH_2-CH_2-$OH)_2$
-C-$(CH_3)_2$	–N(CH_2-CH_2-COO^- .$Na^+)_2$	-N^+(Z-$CH_3)_3$.X^-	-H	-H	-H	-H	-N^+(Z-$CH_3)_3$.X^-	–N(CH_2-CH_2-COO^- .$Na^+)_2$
-C-$(CH_3)_2$	–N(Z-$CH_3)_2$	-OH	–CH_2-N(Z-$CH_3)_2$	–CH_2-N-[CH_2-CH_2-$OH]_2$	–CH_2-N-[Z-$CH_3]_2$	–CH_2-N(CH_2-CH_2-$OH)_2$	-OH	–N(CH_2-CH_2-$OH)_2$

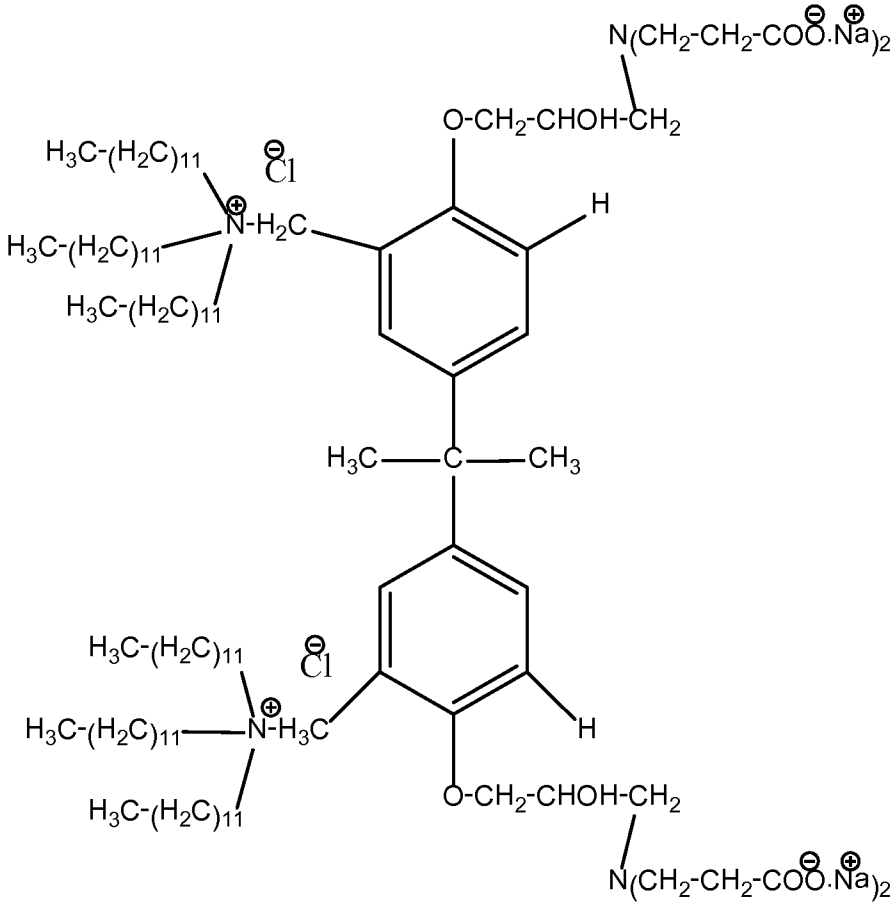
[0068] Examples of compounds represented by formula IV include, but are not limited to, the following compounds:



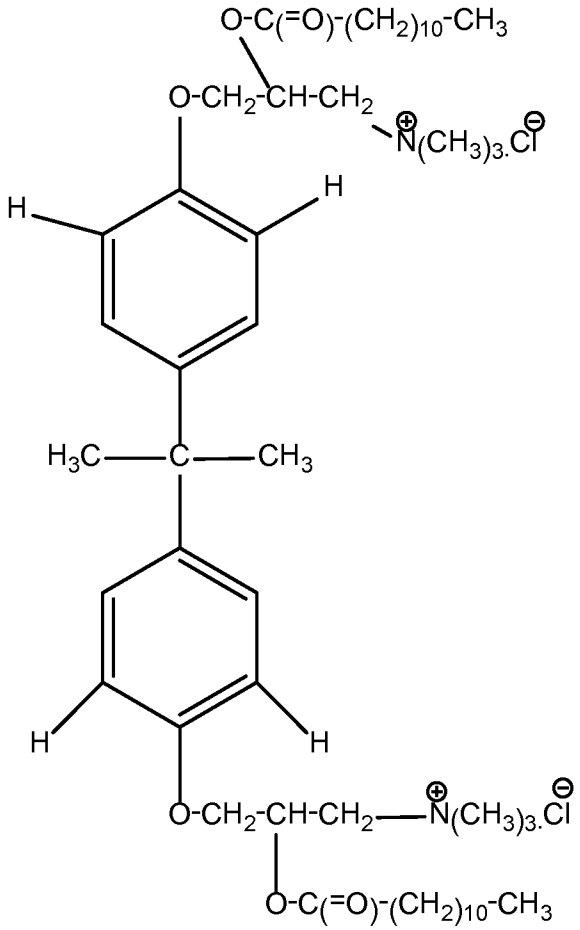
compound 14


N(CH2-CH2OH)2
O-CH2-CHOH-CH2
H3C-(H2C)11
Cl
N-H2C
H3C-(H2C)11
H3C-(H2C)11
H
H3C
C
CH3
H3C-(H2C)11
Cl
N-H2C
H3C-(H2C)11
H3C-(H2C)11
H
O-CH2-CHOH-CH2
N(CH2-CH2OH)2

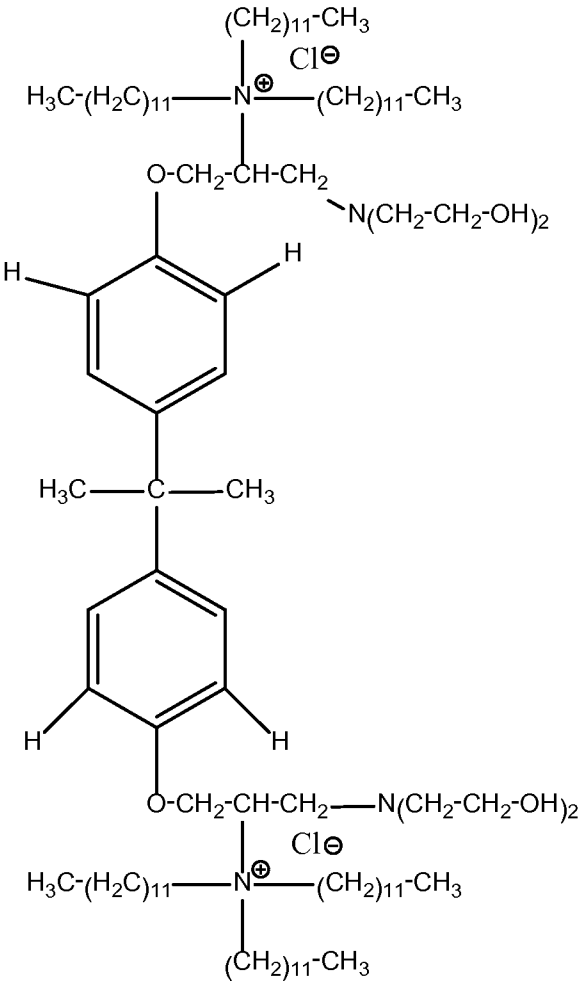
compound 15


N(CH2-CH2-COO.Na)2
O-CH2-CHOH-CH2
H3C-(H2C)11
Cl
N-H2C
H3C-(H2C)11
H3C-(H2C)11
H
H3C
C
CH3
H3C-(H2C)11
Cl
H3C-(H2C)11
N-H3C
H3C-(H2C)11
H
O-CH2-CHOH-CH2
N(CH2-CH2-COO.Na)2

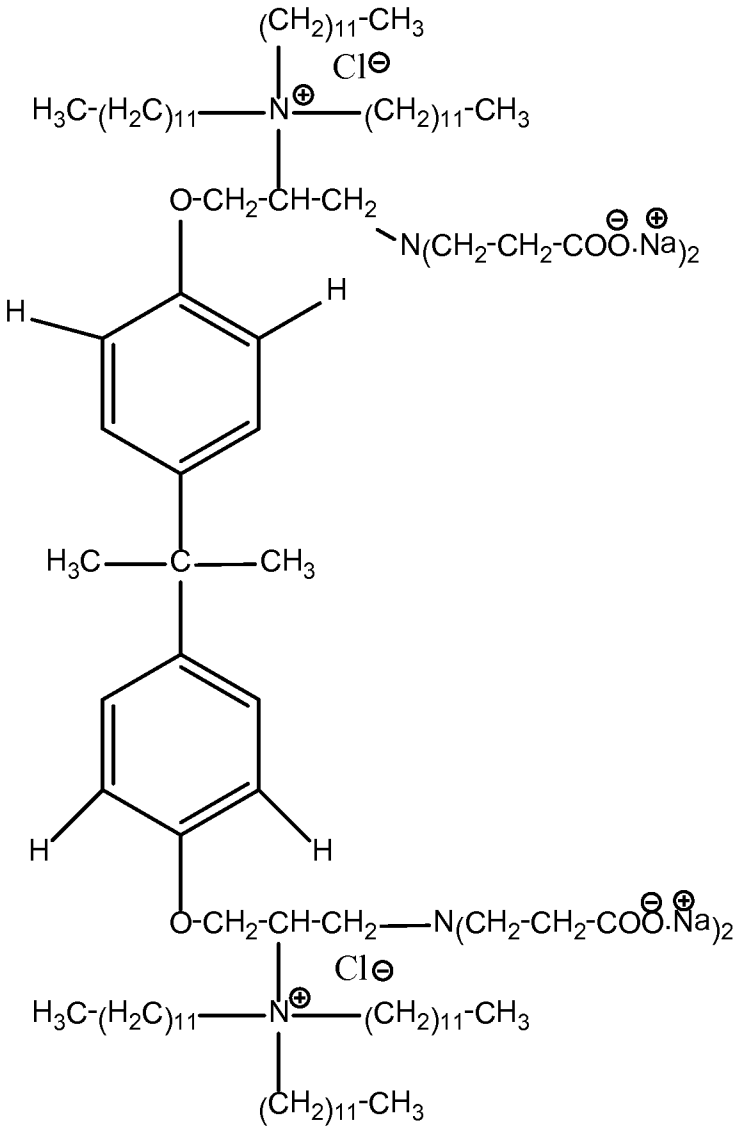
compound 16


O-C(=O)-(CH2)10-CH3
O-CH2-CH-CH2
N(CH3)3.Cl
H
H
H3C
C
CH3
H
H
O-CH2-CH-CH2
N(CH3)3.Cl
O-C(=O)-(CH2)10-CH3

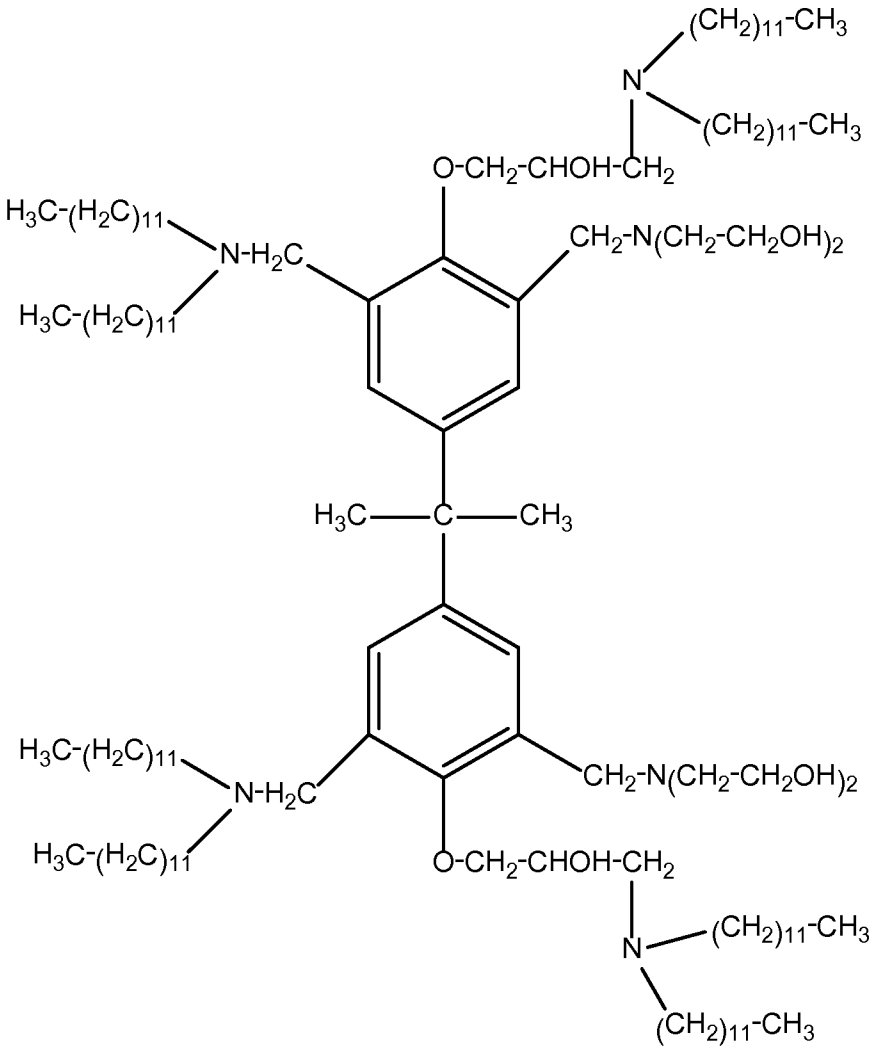
compound 17


(CH2)11-CH3
Cl⊖
H3C-(H2C)11—N⊕—(CH2)11-CH3
O-CH2-CH-CH2
N(CH2-CH2-OH)2
H
H
H3C—C—CH3
H
H
O-CH2-CH-CH2—N(CH2-CH2-OH)2
Cl⊖
H3C-(H2C)11—N⊕—(CH2)11-CH3
(CH2)11-CH3

compound 18

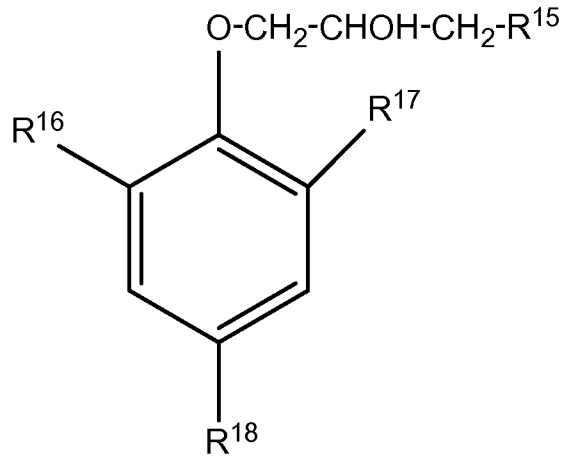


compound 19



compound 20

[0069] In some embodiments, a compound is of formula V:



(V)

wherein R^{15} may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(Z-CH_3)$_3$.X^-, -N^+H_3.X^-, -N^+(CH_3)$_3$.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N-(CH_2-CH_2-COOH)$_2$, or salts thereof. In some embodiments, R^{15} may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(Z-CH_3)$_3$.X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$. In some embodiments, R^{15} may be -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(Z-CH_3)$_3$.X^-, -N^+H_3.X^-, or -N[Z-CH_3]$_2$.

[0070] In some embodiments, R^{16} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , -CH_2-N^+(CH_3)$_3$.X^-, -CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)$_2$, -CH_2-N-(CH_2-CH_2-COOH)$_2$, or salts thereof. In some embodiments, R^{16} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^- , or -CH_2-O-Z-CH_3. In some embodiments, R^{16} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, or -CH_2-NH-CH_2-CH_2-OH.

[0071] In some embodiments, R^{17} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , -CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)$_2$, -CH_2-N-(CH_2-CH_2-COOH)$_2$, or salts thereof. In some embodiments, R^{17} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-O-Z-CH_3, or -CH_2-N^+(Z-CH_3)$_3$.X^- . In some embodiments, R^{17} may be –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH,

-CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, or -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$.

[0072] In some embodiments, R^{18} may be -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^- , -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , -CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)$_2$, -CH_2-N-(CH_2-CH_2-COOH)$_2$, or salts thereof. In some embodiments, R^{18} may be -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$.X^-, -CH_2-O-Z-CH_3, or -CH_2-N^+(Z-CH_3)$_3$.X^-. In some embodiments, R^{18} may be -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$.

[0073] In some embodiments, each Z may be, independently, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent.

[0074] In some embodiments, X may be Cl, Br, F, I, or OH.

[0075] In some embodiments, in compound of formula V, at least one of R^{15}, R^{16}, R^{17}, and R^{18} is hydrophilic, and at least one of R^{15}, R^{16}, R^{17}, and R^{18} is hydrophobic.

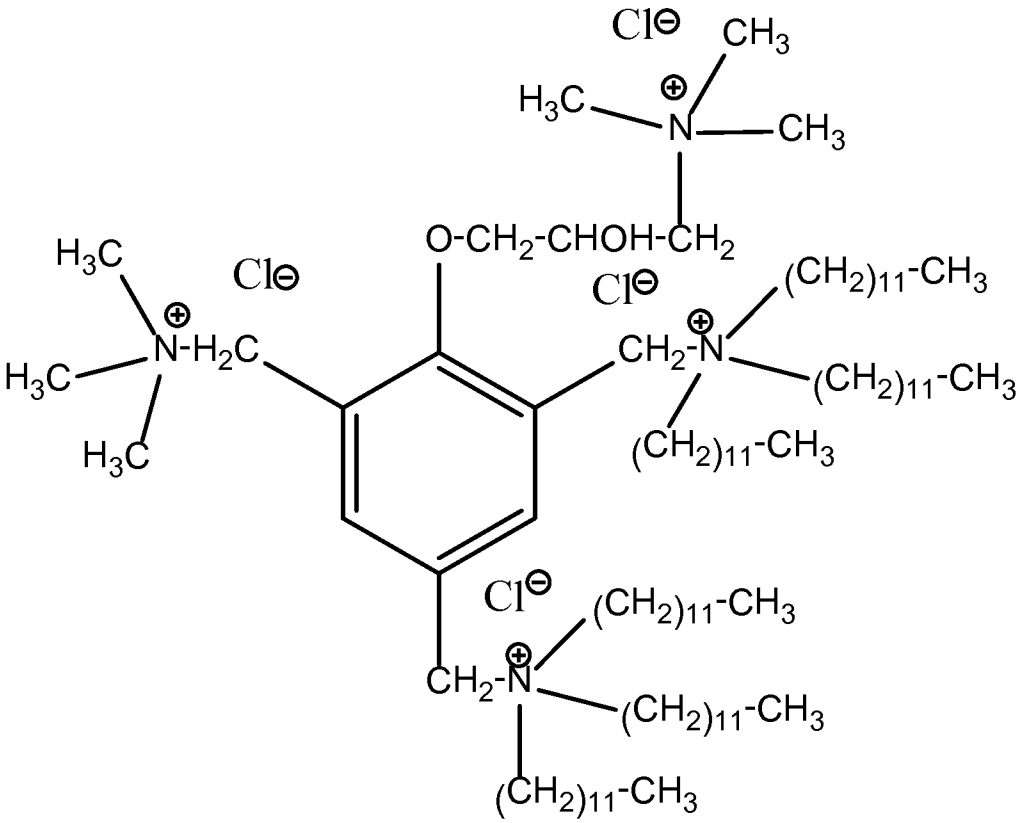
[0076] In some embodiments, the compound of formula V may have substitutions at each of, independently, R^1, R^2, R^3, and R^4 as shown in Table 5:

TABLE 5

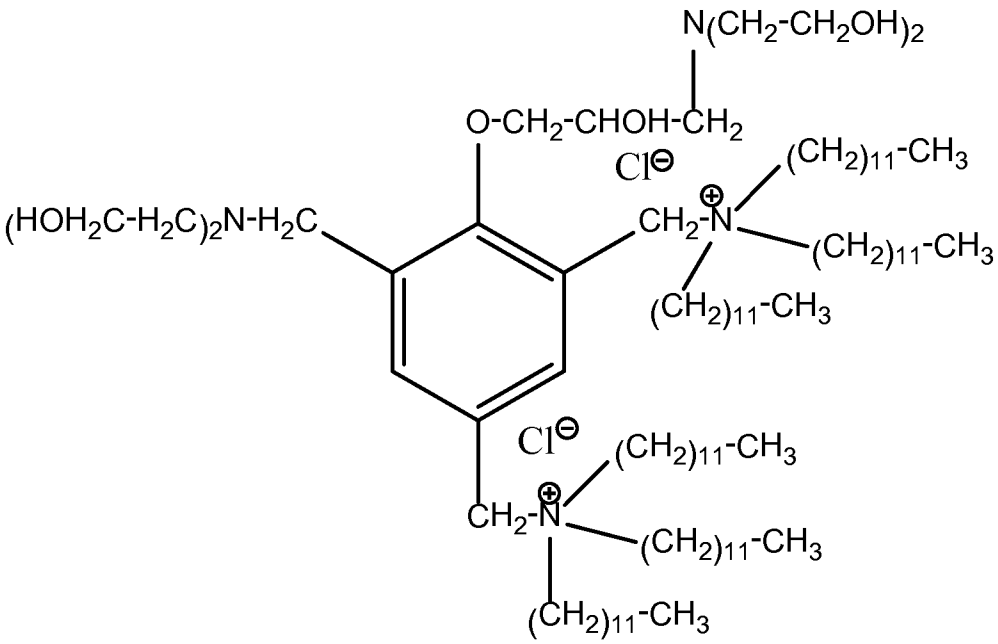
R^{15}	R^{16}	R^{17}	R^{18}
-N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3$$X^-$]$_2$, -$N^+$(Z-$CH_3$)$_3$.$X^-$, -$N^+H_3$.$X^-$,	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-	–H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-	-CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH,

$-N^+(CH_3)_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N-(CH_2-CH_2-COOH)_2$, or salts thereof	CH_2-COOH, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-O-Z-CH_3$, $-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, $-CH_2-N^+(CH_3)_3.X^-$, $-CH_2-N-(CH_2-CH_2-COOH)_2$, or salts thereof	CH_2-COOH, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-O-Z-CH_3$, $-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, $-CH_2-N-(CH_2-CH_2-COOH)_2$, or salts thereof	$-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-O-Z-CH_3$, $-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, $-CH_2-N-(CH_2-CH_2-COOH)_2$, or salts thereof
$-N(-CH_3)-Z-CH_3$, $-N[CH_2-N^+(CH_3)_3X^-]_2$, $-N^+(Z-CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, or $-N-(CH_2-CH_2-OH)_2$	–H, $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, or $-CH_2-N^+(CH_2-CH_2-OH)_3$	–H, $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, or $-CH_2-N^+(CH_2-CH_2-OH)_3$	$-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, or $-CH_2-N^+(CH_2-CH_2-OH)_3$
$-N(-CH_3)-Z-CH_3$, $-N[CH_2-N^+(CH_3)_3X^-]_2$, $-N^+(Z-CH_3)_3.X^-$, $-N^+H_3.X^-$, or $-N[Z-CH_3]_2$	–H, $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, or $-CH_2-O-C(=O)-CH_2-COOH$	–H, $-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, or $-CH_2-N[Z-CH_3]_2$	$-CH_2-O-C(=O)-Z-CH_3$, $-CH_2-N(-CH_3)-Z-CH_3$, $-CH_2-O-C(=O)-CH_2-CH_2-COOH$, $-CH_2-O-C(=O)-CH_2-COOH$, or $-CH_2-N[Z-CH_3]_2$
$-N^+(CH_3)_3.Cl^-$	$-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$	$-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$	$-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$
$-N^+(CH_3)_3.Cl^-$	$-CH_2-N^+(CH_3)_3.Cl^-$	$-CH_2-N^+(Z-CH_3)_3.Cl^-$	$-CH_2-N^+(Z-CH_3)_3.Cl^-$
$-N^+(CH_3)_3.Cl^-$	$-CH_2-N^+(CH_3)_3.Cl^-$	$-CH_2-O-C(=O)-Z-CH_3$	$-CH_2-O-C(=O)-Z-CH_3$
$-N^+(CH_2-CH_2-OH)_3.X^-$	$-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$	$-CH_2-N(Z-CH_3)_2$	$-CH_2-N(Z-CH_3)_2$
$-N-(CH_2-CH_2-OH)_2$,	$-CH_2-N-(CH_2-CH_2-OH)_2$,	$-CH_2-N^+(Z-CH_3)_3.Cl^-$	$-CH_2-N^+(Z-CH_3)_3.Cl^-$
$-N-(CH_2-CH_2-COO^-Na^+)_2$,	$-CH_2-N-(CH_2-CH_2-COO^-Na^+)_2$,	$-CH_2-N^+(Z-CH_3)_3.Cl^-$	$-CH_2-N^+(Z-CH_3)_3.Cl^-$
$-N-(CH_2-CH_2-OH)_2$,	$-CH_2-N-(CH_2-CH_2-OH)_2$,	$-CH_2-N[Z-CH_3]_2$	$-CH_2-N[Z-CH_3]_2$

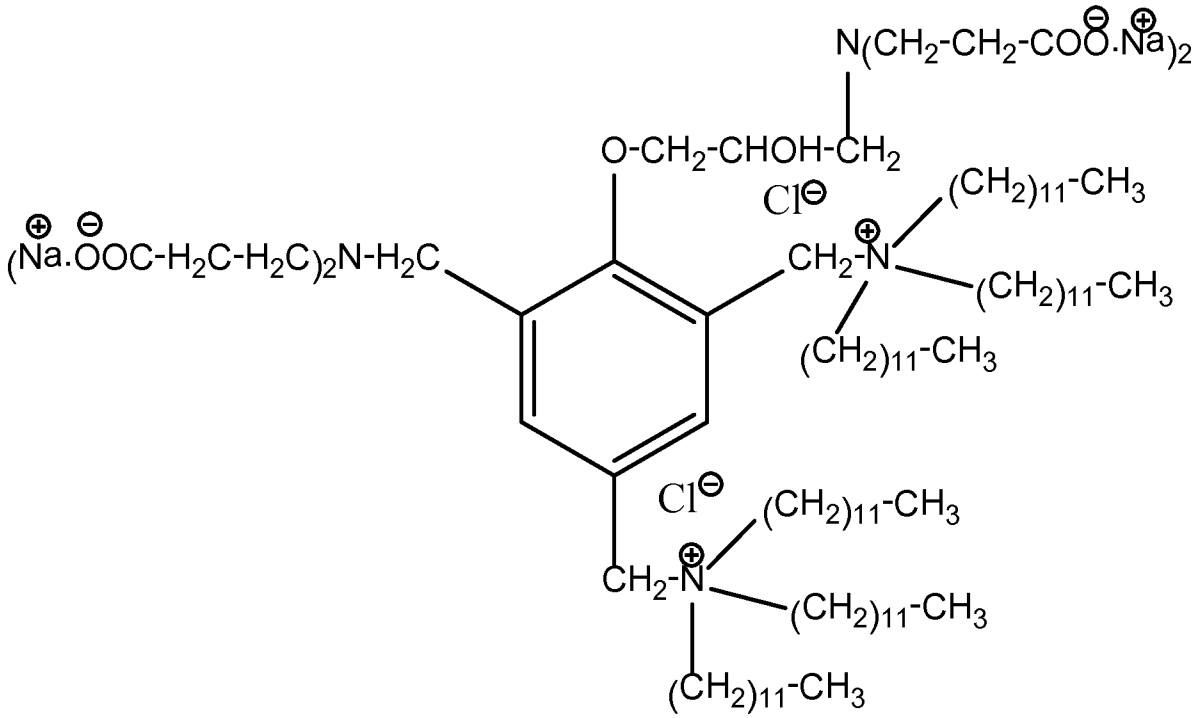
[0077] Examples of compounds represented by formula V include, but are not limited to, the following compounds:



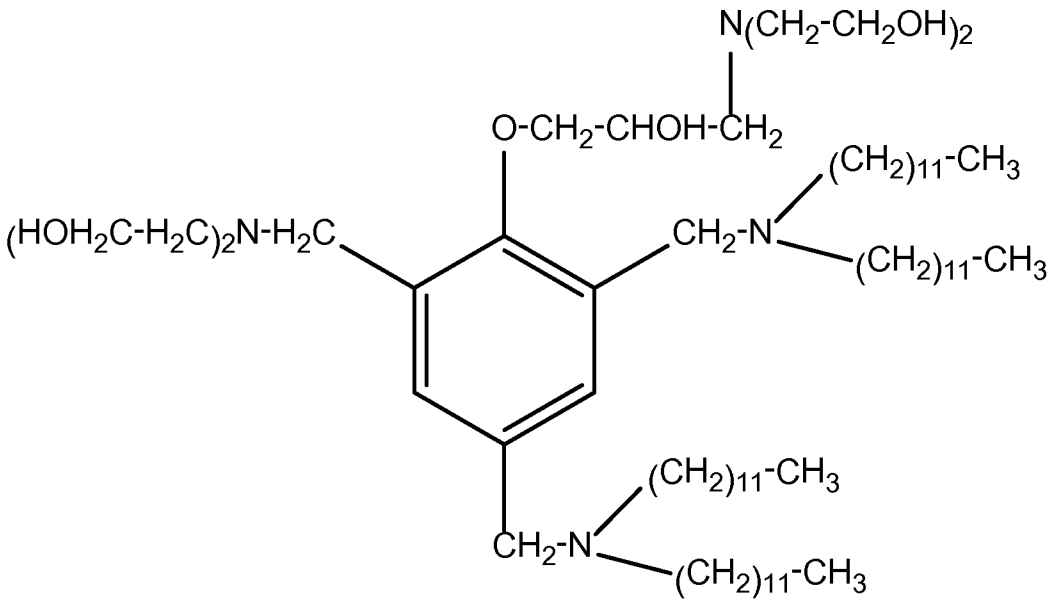
compound 21



compound 22



compound 23



compound 24

[0078] In some embodiments, the compounds represented by formulae I-V may be gemini surfactants. These gemini surfactants may be made more hydrophobic or more hydrophilic depending on the use. For example, increasing the nonpolar chain length of the hydrophobic groups may increase both the lipophilicity and surface activity, with a decrease in the critical micellar concentration. In some embodiments, the ratio of hydrophobic groups to hydrophilic groups may vary in the gemini surfactants described herein.

[0079] In some embodiments, the hydrophobic groups of the gemini surfactants may be an alkyl ether chain, an arylalkyl ether chain, an alkylester chain, or an arylalkylester chain, with suitable chain length. Such chains can act as anchors and prevent leaching of the surfactants when incorporated in paints. In some embodiments, the hydrophilic groups may be monoethanol amine, diethanol amine, or triethanol amine; anionic groups, such as carboxylate, sulphate, sulphonate, monohydrogen phosphate, or dihydrogen phosphate, or salts of Na^+, K^+, Ca^{2+}, Mg^{2+}, or NH_4^+, or any combination thereof; cationic groups, such as quaternary ammonium salts, phosphonium salts, acrylate salts, or any combination thereof.

[0080] In some embodiments, a hydrophilic coating may include one or more of the gemini surfactants of formulae I-V, as described herein. The hydrophilic coating may provide hydrophilic and/or self-cleaning properties when applied on a substrate. As water evaporates, binder particles pack against each other forming an irreversible networked structure. During this process, coalescing agents along with gemini surfactants may migrate to the surface. The gemini surfactant may provide a hydrophilic surface to the coating, thus aiding in self-cleaning of the surface. These surfaces are able to interact and retain water molecules for relatively longer periods of time, thus keeping the surface wet and helping water to sheathe off and remove dirt. In addition, the gemini surfactants may provide anti-bacterial and anti-microbial properties to the coating.

[0081] The hydrophilic coating described herein may be used as a decorative coating, an industrial coating, a protective coating, a UV-protective coating, a self-cleaning coating, a biocidal coating, or any combination thereof. The coatings may generally be applied to any substrate. The substrate may be an article, an object, a vehicle or a structure. Although no particular limitation is imposed on the substrate to be used in the present disclosure, exemplary substrates include an exterior of a building, vehicles, cars, trucks, bicycles, bridges, airplanes, helicopters, metal railings, fences, glasses, plastics, metals, ceramics, wood, stones, cement, fabric, paper, leather, walls, pipes, vessels, medical devices, turbines, fan blades, propellers, and the like. The coating may be applied to a substrate by spraying, dipping, rolling, brushing, or any combination thereof.

[0082] Gemini surfactants may be present in the coating composition at about 0.5 to about 5 weight percent, at about 0.5 to about 2.5 weight percent, at about 0.5 to about 2 weight percent, at about 0.5 to about 1.5 weight percent, or at about 0.5 to about 1 weight percent. Specific examples include about 0.5 weight percent, about 1 weight percent, about 1.5 weight percent, about 2 weight percent, about 2.5 weight percent, about 5 weight percent

of the total weight, and ranges between (and including the endpoints of) any two of these values. Due to the high surface-activity, a much lower concentration of the surfactants may be needed as compared to the conventional surfactants.

[0083] Gemini surfactants may be added to the coating during emulsion polymerization process by substituting the conventional surfactants with the gemini surfactants described herein. In an emulsion polymerization process, the surfactant is dissolved in water until the critical micelle concentration (CMC) is reached. The interior of the micelle provides the site necessary for polymerization. The polymerization process involves heating a mixture containing water, an initiator, monomer and a surfactant with constant stirring. The initiator/surfactant mixture and monomer are vigorously mixed to form micelles. In some embodiments, the gemini surfactants may be mixed with conventional surfactants during this process. Examples of conventional surfactants that may be used include, but are not limited to, alkyl phenol ethoxylates, sodium lauryl sulfate, dodecylbenzenesulfonate, polyoxyethylene alkyl ethers, polyoxyethylene alkyl allyl ethers, ethylene glycols, polyoxyethylene, stearic acid and polyoxypropylene. In some embodiments, the gemini surfactants may be incorporated in the paint composition at the end of the process, and mixed with the paint before use. For example, an end consumer may add the gemini surfactant to any conventional paint formulation before use.

[0084] In some embodiments, the gemini surfactants in the paint composition may exist as molecules cross-linked to each other. The presence of cross-linking groups, such as acrylene or styrylene groups may be involved in this cross-linking. In some embodiments, the gemini surfactants may exist as free molecules without cross-links. In addition, the gemini surfactants may also exist as cross-linked to the binder component. The binder may be an acrylate, styrenic or a vinyl polymer. Suitable binder polymers may be polymers of alkylacrylate, alkyl methacrylate, allyl methacrylate, acrylic acid, methacrylic acid,

acrylamide, 2-hydroxyethyl methacrylate, 2-hydroxypropyl methacrylate, thioethyl methacrylate, vinyl methacrylate, vinyl benzene, 2-hydroxyethyl acrylate, butyl acrylate, 2-ethylhexyl acrylate, vinyltrimethoxysilane, vinyltriethoxysilane, vinyl formate, vinyl acetate, vinyl propionate, vinyl butyrate, vinyl hexanoate, vinyltoluene, α-methyl styrene, chlorostyrene, or styrenesulfonic acid, or a copolymer of any of the foregoing, or any combination thereof.

[0085] In addition, the gemini surfactants described herein may function as efficient emulsifiers and coalescing agents in paints. The gemini surfactants may self-crosslink or cross-link with the binder and may reduce minimum film forming temperature (MFT). These gemini surfactants may function as non-leachable emulsifying agents due to anchoring of the hydrophobic chains, in addition to the electrostatic and physical chain entanglements with polymeric binder chains. Further, these gemini surfactants may form stable emulsion systems with improved resistance to coagulation when subjected to low temperature or high shear stress.

[0086] The gemini surfactants described herein may behave as multi-activity surfactants: anionic, cationic, molecular and mixed activity gemini surfactants. Further, the ratio of hydrophobic/hydrophilic active groups may be controlled according to the required application. Furthermore, the gemini surfactants described herein may be combined with one or more classes of surfactants, irrespective of active groups, whether aliphatic, aromatic or heterocyclic.

[0087] In addition to its use in paints, the gemini surfactants may also be used as a hydrophilic material, a defoamer, an emulsifier, a dispersant for diesel fuel mixtures, a wetting aid, a leveling aid, a phase transfer catalyst, or a demulsifying agent.

[0088] Gemini surfactants may also be used in sunscreens, skin-cleansing compositions, dermatology and acne care products (for example, soaps, specialty soaps,

liquid hand soaps, shampoos, conditioners, shower gels), household products (for example, dry and liquid laundry detergents, dish soaps, dishwasher detergents, toilet bowl cleaners, upholstery cleaners, glass cleaners, general purpose cleaners, or fabric softeners), hard surface cleaners (for example, floor cleaners, metal cleaners, automobile and other vehicle cleaners), pet care products (for example, shampoos), and cleaning products in general. Other uses for gemini surfactants may be found in industrial applications in lubricants, emulsion polymerization, textile processing, mining flocculates, petroleum recovery, dispersants for pigments, wetting or leveling agents in paints and printing inks, wetting agents for household and agricultural pesticides, wastewater treatment and collection systems, off-line and continuous cleaning, and manufacture of cross-flow membrane filters, such as reverse osmosis (RO), ultra filtration (UF), micro filtration (MF) and nano filtration (UF), plus membrane bioreactors (MBRs), and all types of flow-through filters including multi-media filters, and many other products and processes. Further, the gemini surfactants may also be used as dispersants for tramp oil in cooling towers and after oil spills.

Preparation of gemini surfactants of formula I

[0089] In some embodiments, a method of making a gemini surfactant of formula I may include contacting any one of urea, biuret, or alkylene diamine with formaldehyde to form a hydroxymethyl compound; and contacting the hydroxymethyl compound with a dimethyl alkyl amine to form the gemini surfactant of formula I. In some embodiments, the alkyl group in the dimethyl alkyl amine may be C_1-C_{25} carbon atoms long. In some embodiments, the urea, biuret, or alkylene diamine may be contacted with formaldehyde in a molar ratio from about 1:2 to about 1:6, from about 1:2 about 1:5, from about 1:2 to about 1:4, or from about 1:2 to about 1:3. Specific examples include, but are not limited to, about 1:2, about 1:3, about 1:4, about 1:5, about 1:6, and ranges between any two of these values. The alkylene diamine may be C_1-C_{10} alkylene diamine, particularly ethylene diamine. This

process may be conducted in the presence of a basic catalyst. Specific examples of the basic catalyst include alkali metal hydroxides, such as KOH, LiOH, NaOH, and the like. Contacting any one of urea, biuret, or alkylene diamine with the formaldehyde and the basic catalyst may be performed in a solution. During this process, the pH of the solution may be maintained from about pH 8 to about pH 11, from about pH 8 to about pH 10.5, from about pH 8 to about pH 10, from about pH 8 to about pH 9, or from about pH 8 to about pH 8.5. Specific examples include, but are not limited to, about pH 8, about pH 8.5, about pH 9, about pH 9.5, about pH 10, about pH 11, and ranges between any two of these values (including their endpoints).

[0090] When contacting any one of urea, biuret, or alkylene diamine with the formaldehyde and the basic catalyst, the mixture may be heated to a temperature of about 50 °C to about 90 °C, about 50 °C to about 75 °C, about 50 °C to about 70 °C, or about 50 °C to about 60 °C. Specific examples also include, but are not limited to, about 50 °C, about 65 °C, about 70 °C, about 80 °C, about 85 °C, about 90 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0091] In some embodiments, when contacting the hydroxymethyl compound with the dimethyl alkyl amine, the mixture may be heated to a temperature of about 20 °C to about 40 °C, about 20 °C to about 35 °C, about 20 °C to about 30 °C, or about 20 °C to about 25 °C. Specific examples also include, but are not limited to, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2

hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values. In some embodiments, the hydroxymethyl compound may be a di(hydroxymethyl) compound, a tri(hydroxymethyl) compound, a tetra(hydroxymethyl) compound, a poly(hydroxymethyl) compound, or any combination thereof.

Preparation of gemini surfactants of formula II

[0092] In some embodiments, gemini surfactants of formula II may be prepared by contacting melamine with formaldehyde to form a hydroxymethyl melamine derivative; contacting the hydroxymethyl melamine derivative with diethanolamine to form a diethanol melamine derivative; and contacting the diethanol melamine derivative with an alkyl halide.

[0093] In some embodiments, while contacting melamine with formaldehyde, the mixture may be heated to a temperature of about 50 °C to about 90 °C, about 50 °C to about 75 °C, about 50 °C to about 70 °C, or about 50 °C to about 60 °C. Specific examples also include, but are not limited to, about 50 °C, about 65 °C, about 70 °C, about 80 °C, about 85 °C, about 90 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0094] In some embodiments, the hydroxymethyl melamine derivative is further reacted with diethanol amine, and the mixture may be heated to a temperature of about 20 °C to about 40 °C, about 20 °C to about 35 °C, about 20 °C to about 30 °C, or about 20 °C to about 25 °C. Specific examples also include, but are not limited to, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, and ranges between (and including the endpoints of)

any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values. In some embodiments, the hydroxymethyl melamine derivative may be a tri(hydroxymethyl) melamine derivative, a tetra(hydroxymethyl) melamine derivative, a penta(hydroxymethyl) melamine derivative, a hexa(hydroxymethyl) melamine derivative, or any combination thereof.

[0095] The melamine with diethanol amine functional groups may be further reacted with an alkyl halide, and the reaction may be heated to a temperature of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 35 °C, about 40 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values. In some embodiments, the alkyl chloride may be C_1-C_{25} carbon atoms in length.

[0096] In some embodiments, gemini surfactants of formula II may be prepared by contacting melamine with formaldehyde to form a hydroxymethyl melamine derivative; and contacting the hydroxymethyl melamine derivative with one of the following: an equimolar mixture of saturated fatty acid/oxalic acid, an equimolar mixture of saturated fatty acid/chlorosulfonic acid or an equimolar mixture of saturated fatty acid/ chlorophosphonic acid.

[0097] In some embodiments, while contacting the hydroxymethyl melamine derivative with an equimolar mixture of saturated fatty acid/oxalic acid, an equimolar mixture of saturated fatty acid/chlorosulfonic acid or an equimolar mixture of saturated fatty acid/ chlorophosphonic acid, the reaction mixture may be heated to a temperature of about 30 °C to about 80 °C, about 30 °C to about 75 °C, about 30 °C to about 60 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 55 °C, about 60 °C, about 75 °C, about 80 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0098] In some embodiments, gemini surfactants of formula II may be prepared by contacting melamine with formaldehyde to form a hydroxymethyl melamine derivative; and contacting the hydroxymethyl melamine derivative with a dimethyl alkylamine.

[0099] In some embodiments, the hydroxymethyl melamine derivative may be reacted dimethyl alkyl amine, and the mixture may be heated to a temperature of about 20 °C to about 40 °C, about 20 °C to about 35 °C, about 20 °C to about 30 °C, or about 20 °C to about 25 °C. Specific examples also include, but are not limited to, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 2 hours to about 6 hours, about 2 hours to about 5 hours, about 2 hours to about 4 hours, or about 2 hours to about 3 hours. Specific examples include, but are not limited to, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

Preparation of gemini surfactants of formula III

[0100] In some embodiments, gemini surfactants of formula III may be prepared by contacting novolac with epichlorohydrin to form a novolac-chlorohydrin derivative; contacting the novolac-chlorohydrin derivative with diethanolamine or triethylamine to form a novolac derivative; and contacting the novolac derivative with an alkyl chloride.

[0101] In some embodiments, the novolac and epichlorohydrin mixture may be heated to a temperature of about 50 °C to about 90 °C, about 50 °C to about 75 °C, about 50 °C to about 70 °C, or about 50 °C to about 60 °C. Examples also include about 50 °C, about 65 °C, about 70 °C, about 80 °C, about 85 °C, about 90 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for a variety of times, such as about 2 hours to about 6 hours, for about 2 hours to about 5 hours, for about 2 hours to about 4 hours, or for about 2 hours to about 3 hours. Examples also include about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (an including the endpoints of) any two of these values.

[0102] In some embodiments, the novolac-chlorohydrin derivative may be reacted with either diethanol amine or triethyl amine to form a novolac derivative. The reaction may be performed at a temperature of about 50 °C to about 90 °C, about 50 °C to about 75 °C, about 50 °C to about 70 °C, or about 50 °C to about 60 °C. Examples also include about 50 °C, about 65 °C, about 70 °C, about 80 °C, about 85 °C, about 90 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for a variety of times, such as about 1 hour to about 3 hours, for about 1 hours to about 2 hours, or for about 1 hour to about 1.5 hours. Examples also include about 1 hour, about 1.5 hours, about 2 hours, about 3 hours, and ranges between (an including the endpoints of) any two of these values.

[0103] In some embodiments, the novolac derivative may be reacted with an alkyl chloride, and the alkylation may be performed by any alkylation process known in the art. For example, the alkylation may be performed in the presence of a Friedel-Crafts catalyst, such as $AlCl_3$. The alkyl halide may be any C_1-C_{25} carbon atom alkyl halide.

Preparation of gemini surfactants of formula IV

[0104] In some embodiments, the gemini surfactants of formula IV may be prepared by contacting a bisphenol compound with epichlorohydrin and formaldehyde to form a tetramethylol bisphenol derivative; contacting the tetramethylol bisphenol derivative with any one of the following: an equimolar mixture of trimethylamine and N,N,N,-trialkyl amine, an equimolar mixture of diethanol amine and N,N,N,-trialkyl amine, and an equimolar mixture of disodium propionate amine and N,N,N,-trialkyl amine.

[0105] In some embodiments, a bisphenol compound may be contacted with epichlorohydrin and formaldehyde to form a tetramethylol bisphenol derivative. Non-limiting examples of bisphenol compound include bisphenol A, bisphenol F, bisphenol S, bisphenol sulphone, bisphenol sulphoxide, bisphenol chloral, bisphenolvinylidene dichloride, and bisphenol methylenedifluoride.

[0106] In some embodiments, the tetramethylol bisphenol derivative may be reacted with an equimolar mixture of trimethylamine and N,N,N,-trialkyl amine, and the reaction may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include,

but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0107] In some embodiments, the tetramethylol bisphenol derivative may be reacted with an equimolar mixture of diethanol amine and N,N,N,-trialkyl amine, and the reaction may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include, but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0108] In some embodiments, the tetramethylol bisphenol derivative may be reacted with an equimolar mixture of disodium propionate amine and N,N,N,-trialkyl amine, and the reaction may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include, but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

Preparation of gemini surfactants of formula V

[0109] In some embodiments, the gemini surfactants of formula V may be prepared by reacting a resol with epichlorohydrin to form a resol-chlorohydrin derivation;

and contacting the resol-chlorohydrin derivative with any one of the following: an equimolar mixture of triethylamine and N,N,N,-trialkyl amine, an equimolar mixture of diethanol amine and N,N,N,-trialkyl amine, an equimolar mixture of disodium propionate amine and N,N,N,-trialkyl amine.

[0110] In some embodiments, while contacting resol and epichlorohydrin, the mixture may be heated to a temperature of about 50 °C to about 90 °C, about 50 °C to about 75 °C, about 50 °C to about 70 °C, or about 50 °C to about 60 °C. Examples also include about 50 °C, about 65 °C, about 70 °C, about 80 °C, about 85 °C, about 90 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for a variety of times, such as about 2 hours to about 6 hours, for about 2 hours to about 5 hours, for about 2 hours to about 4 hours, or for about 2 hours to about 3 hours. Examples also include about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (an including the endpoints of) any two of these values.

[0111] In some embodiments, the resol-chlorohydrin derivative may be reacted with an equimolar mixture of triethylamine and N,N,N,-trialkyl amine, and the reaction may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include, but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0112] In some embodiments, the resol-chlorohydrin derivative may be reacted with an equimolar mixture of diethanol amine and N,N,N,-trialkyl amine, and the reaction

may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include, but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

[0113] In some embodiments, the resol-chlorohydrin derivative may be reacted with an equimolar mixture of disodium propionate amine and N,N,N,-trialkyl amine, and the reaction may be performed at temperatures of about 30 °C to about 60 °C, about 30 °C to about 55 °C, about 30 °C to about 50 °C, or about 30 °C to about 40 °C. Specific examples also include, but are not limited to, about 30 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, and ranges between (and including the endpoints of) any two of these values. The heating may be performed for about 1 hour to about 6 hours, about 1 hour to about 5 hours, about 1 hour to about 4 hours, or about 1 hour to about 3 hours. Specific examples include, but are not limited to, about 1 hour, about 3 hours, about 4 hours, about 5 hours, about 6 hours, and ranges between (and including the endpoints of) any two of these values.

EXAMPLES

EXAMPLE 1: Preparation of compound 2

[0114] About 60 grams of urea (1 mole) and 324 grams (4 moles) of formalin solution (37% concentration) were mixed in a five-neck flanged top reaction flask fitted with a condenser, mechanical stirrer, dropping funnel, and a thermometer. The reaction was started by adding 40% sodium hydroxide solution drop wise, and the pH of the reaction mixture was adjusted to pH 10. The reaction mixture was heated to about 65 °C for 2 hours

with mixing, and the pH was maintained at pH 9 - pH 10. At the end of the reaction period, the reaction mixture was cooled and neutralized with a cold (5-10 °C) solution of sodium dihydrogen phosphate. The product was desalted and dried with molecular sieves. The product was evaporated by rotary evaporators and dried under vacuum to obtain a hydroxymethyl compound. The number of hydroxymethyl groups was determined by using moisture evolution analysis technique and thermogravimetric analysis.

[0115] The above obtained hydroxymethyl compound (63.5 grams, 0.5 mole) was dissolved in methanol and added drop wise to two moles of N,N-dimethyl heneicosylamine at 30 °C. The mixture was maintained at 30 °C and mixed for two hours, and gradually heated to 60 °C. The reaction was continued for further one hour under stream of nitrogen gas. The product was desalted and dried with molecular sieves. The product was evaporated by rotary evaporators and dried under vacuum to obtain the cationic gemini surfactant compound **2**.

EXAMPLE 2: Preparation of compound 6

[0116] A three necked reaction vessel fitted with reflux condenser, thermometer, and mechanical stirrer is charged with 126 grams of melamine (1 mole), and 8 moles of formalin solution (37 weight %). A 10% (weight %) sodium carbonate solution is added and the pH is maintained between 8.5-9. The solution is heated to 65-70 °C for 3 hours with continuous mixing. At the end of this period, product is cooled to room temperature and excess of non-reacted formaldehyde is removed to obtain hexa-hydroxymethyl melamine.

[0117] A flanged top reaction vessel fitted with mechanical stirrer, thermometer, condenser and dropping funnel is charged with diethanol amine (107 grams, 1 mole). About 0.5 mole of hexa-hydroxymethyl melamine obtained above is dissolved in 150 grams ethanol and slowly added through the dropping funnel. The temperature of the reaction mixture is controlled at 30 °C and the hexa-hydroxymethyl melamine is added dropwise and mixed for 3

hours at 60 °C. At the end of this period, the unreacted product and ethanol are separated by rotary evaporation under vacuum to obtain a diethanol melamine derivative.

[0118] The above obtained diethanol melamine derivative is dissolved in 100 grams of dioxane or tetrahydrofuran (THF) and added drop wise to one mole of docosanoic acid chloride at 30 °C. The mixture is heated to 50 °C and mixed for three hours. Later, the mixture is cooled to room temperature and the product is neutralized with 10 % (weight %) sodium bicarbonate. The solvent and water are evaporated and the fatty acid salt is separated by extraction. The final product is re-dissolved, desalted and dried with molecular sieves to obtain the non-ionic gemini surfactant compound **6**.

EXAMPLE 3: Preparation of compound 7

[0119] The hexa-hydroxymethyl melamine compound of Example 2 (1 mole) is dissolved in THF and added drop wise to two moles of a mixture containing 1:1 (weight by weight) docosanoic acid chloride and oxalic acid at 30 °C. The mixture is heated to 70 °C and mixed for 2 hours, and later cooled to room temperature. The product is neutralized with 10 % (weight %) sodium bicarbonate, desalted and dried with molecular sieves. The product is evaporated by rotary evaporators and dried under vacuum to obtain the anionic gemini surfactant compound **7**.

EXAMPLE 4: Preparation of compound 8

[0120] The hexa-hydroxymethyl melamine compound of Example 2 (1 mole) is dissolved in THF and added drop wise to two moles of a mixture containing 1:1 (weight by weight) docosanoic acid chloride and chlorosulfonic acid at 30 °C. The mixture is heated to 70 °C and mixed for 2 hours, and later cooled to room temperature. The product is neutralized with 10 % (weight %) sodium bicarbonate, desalted and dried with molecular

sieves. The product is evaporated by rotary evaporators and dried under vacuum to obtain the sulfonate anionic gemini surfactant compound **8**.

EXAMPLE 5: Preparation of compound 9

[0121] The hexa-hydroxymethyl melamine compound of Example 2 (1 mole) is dissolved in THF and added drop wise to two moles of a mixture containing 1:1 (weight by weight) docosanoic acid chloride and chlorophosphoric acid at 30 °C. The mixture is heated to 70 °C and mixed for an additional 2 hours, and later cooled to room temperature. The product is neutralized with 10 % (weight %) sodium bicarbonate, desalted and dried with molecular sieves. The product is evaporated by rotary evaporators and dried under vacuum to obtain the phosphate anionic gemini surfactant compound **9**.

EXAMPLE 6: Preparation of compound 10

[0122] The hydroxyl methyl melamine compound of Example 2 (0.5 mole) is dissolved in methanol and added drop wise to two moles of N,N-dimethyl heneicosylamine at 30 °C. The mixture is kept at 30 °C and mixed for two hours. The product is desalted and dried with molecular sieves. The product is evaporated by rotary evaporators and dried under vacuum to obtain the cationic gemini surfactant compound **10**.

EXAMPLE 7: Preparation of compound 11

[0123] A reaction vessel fitted with a condenser, a mechanical stirrer, and a thermometer is heated in water bath at 65 °C and charged with 0.1 mole of novolac dissolved in 20 % (weight %) sodium hydroxide solution. The solution is reacted with 0.5 mole of epichlorohydrin in the presence of sodium hydroxide to obtain a novolac-chlorohydrin derivative. The novolac-chlorohydrin derivative is further reacted with 0.5 mole triethylamine, resulting in modification of chlorohydrin groups to quaternary ammonium hydroxides. The resulting product is further reacted with 0.3 moles of docosyl chloride in the

presence of a Friedel-Crafts catalyst ($AlCl_3$). The final product is evaporated by rotary evaporators and dried under vacuum to obtain the cationic gemini surfactant compound **11**.

EXAMPLE 8: Preparation of compound 12

[0124] A reaction vessel is charged with 0.1 mole of novolac dissolved in 20% sodium hydroxide solution. The reaction mixture is flushed with nitrogen and heated to 70 ^{o}C. About 0.5 mole of sodium chloroacetate is added slowly and mixed. The reaction is continued for one hour to ensure that all the phenoxy groups are transferred to ether carboxylate groups. The product obtained is alkylated with 0.5 mole of docosyl chloride in the presence of a Friedel-Crafts catalyst ($AlCl_3$). The final product is evaporated by rotary evaporators and dried under vacuum to obtain the carboxylate based anionic gemini surfactant compound **12**.

EXAMPLE 9: Preparation of compound 13

[0125] A reaction vessel fitted with a condenser, a mechanical stirrer, and a thermometer is heated in water bath at 65 ^{o}C and charged with 0.1 mole of novolac dissolved in 20 % sodium hydroxide solution. The solution is reacted with 0.5 mole of epichlorohydrin in the presence of sodium hydroxide to obtain a novolac chlorohydrin derivative. Further, the novolac chlorohydrin derivative (0.3 mole) is added to an excess amount of diethanol amine at 70 ^{o}C and the reaction is continued for one more hour. The excess of unreacted diethanolamine is separated and the product is alkylated by reacting with 0.5 mole of docosyl chloride in the presence of a Friedel-Crafts catalyst. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **11**.

EXAMPLE 10: Preparation of compound 14

[0126] A reaction vessel fitted with a condenser, a dropping funnel, a mechanical stirrer, and a thermometer is charged with 22.8 grams (0.1 mole) of bisphenol-A, 8 grams of

sodium hydroxide (as 20 weight % solution), and 0.3 mole of epichlorohydrin. About 0.6 mole of formaldehyde (as 37 weight % formalin solution) is added through the dropping funnel and mixed to form a tetramethylol bis-chlorohydrin derivative. The obtained product is mixed with an equimolar mixture of N,N,N-trimethylamine and N,N,N- tri-dodecylamine and stirred for two hours at 25 ^{0}C. The reaction is further continued at 50 ^{o}C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the cationic gemini surfactant compound **14**.

EXAMPLE 11: Preparation of compound 15

[0127] A reaction vessel fitted with a condenser, a dropping funnel, a mechanical stirrer, and a thermometer is charged with 22.8 grams (0.1 mole) of bisphenol-A, 8 grams of sodium hydroxide (as 20 weight % solution), and 0.3 mole of epichlorohydrin. About 0.6 mole of formaldehyde (as 37 weight % formalin solution) is added through the dropping funnel and mixed to form a tetramethylol bis-chlorohydrin derivative. The obtained product is mixed with an equimolar mixture of diethanolamine and N,N,N- tri-dodecylamine and stirred for two hours at 25 ^{0}C. The reaction is further continued at 50 ^{o}C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **15**.

EXAMPLE 12: Preparation of compound 16

[0128] A reaction vessel fitted with a condenser, a dropping funnel, a mechanical stirrer, and a thermometer is charged with 22.8 grams (0.1 mole) of bisphenol-A, 8 grams of sodium hydroxide (as 20 weight % solution), and 0.3 mole of epichlorohydrin. About 0.6 mole of formaldehyde (as 37 weight % formalin solution) is added through the dropping funnel and mixed to form a tetramethylol bis-chlorohydrin derivative. The obtained product is mixed with an equimolar mixture of N,N-disodium aminopropionate and N,N,N-tri-

dodecylamine and stirred for two hours at 25 ^{0}C. The reaction is further continued at 50 ^{o}C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the carboxylate anionic gemini surfactant compound **16**.

EXAMPLE 13: Preparation of compound 17

[0129] About 34 grams (0.1 mole) of commercial liquid epoxy resin of Bisphenol-A epoxy resin is mixed with N,N,N-trimethylamine and stirred at 60 ^{o}C for one hour. The resulting product is added slowly to dodecanoic acid chloride (0.2 mole) and further stirred for one hour at 70 ^{o}C. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the cationic gemini surfactant compound **17**.

EXAMPLE 14: Preparation of compound 18

[0130] About 34 grams of commercial liquid epoxy resin of Bisphenol-A epoxy resin is added slowly to an equimolar mixture of N,N-diethanol amine and N,N,N-tri-dodecylamine, and mixed at 30 ^{o}C for one hour. The mixture is further heated to 100 ^{o}C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **18**.

EXAMPLE 15: Preparation of compound 19

[0131] About 34 grams of commercial liquid epoxy resin of Bisphenol-A is added slowly to an equimolar mixture of N,N-disodium aminopropionate and N,N,N-tri-dodecylamine, and mixed at 30 ^{o}C for one hour. The mixture is further heated to 100 ^{o}C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **19**.

EXAMPLE 16: Preparation of compound 20

[0132] A reaction vessel is charged with 22.8 grams (0.1 mole) of bisphenol-A and 8 grams (0.2 mole) of sodium hydroxide (as 20 weight % solution), and heated to 65 ^{o}C.

About 4 moles of formaldehyde (as 37% w/w formalin solution) is added and the reaction is continued at 65 °C for three hours, maintaining the pH at 9-10. The tetra-methylol bisphenol-A formed is reacted with mixture of 0.2 mole of diethanolamine and 0.2 mole of N,N-didodecyl amine at ambient temperature, and then heated to 60 °C for two hours.

[0133] The product formed above is reacted with 0.2 mole of epichlorohydrin at pH 9-10 at 65 °C. The epichlorohydrin derivative is added slowly to an equimolar mixture of N,N-diethanol amine and N,N,di-dodecylamine, and mixed at 30 °C for one hour. The mixture is further heated to 100 °C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **20**.

EXAMPLE 17: Preparation of compound 21

[0134] A reaction vessel is charged with 18 grams (0.1 mole) of resol dissolved in 0.1 mole sodium hydroxide (as 20 weight % solution) and reacted with 0.1 mole of epichlorohydrin at pH 9-10, and at temperature 65-70 °C. The reaction is continued for two hours with efficient mixing. The chlorohydrin derivative obtained is reacted with an equimolar mixture of N,N,N-triethylamine and N,N,N-tri dodecylamine. The reaction is carried out at 30 °C for two hours, and then further continued at 60 °C for one hour. The final product is evaporated by rotary evaporators and dried under vacuum to obtain the gemini surfactant compound **21**.

EXAMPLE 18. A hydrophilic paint with gemini surfactant

[0135] About 10 grams of compound **2** is mixed with 40 grams of TiO_2, 2 grams of thickener (hydroxyethyl cellulose), 150 grams of solvent (water), 70 grams of binder (methyl methacrylate), 0.3 grams of coalescing agent (2,2,4-trimethyl-1,3-pentanediolmono(2-methylpropanoate)), and 0.05 grams of bactericide. The components are

mixed under high shear for 30 minutes. The hydrophilic characteristics of the paint were investigated and evaluated.

EXAMPLE 19. A hydrophilic paint with gemini surfactant

[0136] About 10 grams of compound **14** is mixed with 40 grams of TiO_2, 2 grams of thickener (hydroxyethyl cellulose), 150 grams of solvent (water), 70 grams of binder (methyl methacrylate), 0.3 grams of coalescing agent (2,2,4-trimethyl-1,3-pentanediolmono(2-methylpropanoate)), and 0.05 grams of bactericide. The components are mixed under high shear for 30 minutes.

EXAMPLE 20: Evaluation of hydrophilic property

[0137] The coating preparation of Example 18 is coated on a glass surface and dried at room temperature. The surface free energy and the water droplet contact angle of the hydrophilic coating are measured as follows. A Zisman plotting method is employed for measuring the surface free energy. The surface tension of various concentrations of the aqueous solution of magnesium chloride is plotted along the X-axis, and the contact angle in terms of cos θ is plotted along the Y-axis. A graph with a linear relationship between the two is obtained. The graph is extrapolated such that the surface tension at contact angle 0° is measured and is defined as the surface free energy of the coated glass surface. The surface free energy of the glass surface measured will be 82 milliNewton/meter. The high surface free energy is indicative of the hydrophilic property of the coating.

EXAMPLE 21: Evaluation of hydrophilic coating

[0138] A hydrophilic coating of Example 19 is coated on a glass substrate and evaluated for the following properties.

[0139] Hydrophilicity: The water droplet contact angle in air is measured by using DropMaster 500 (Kyowa Interface Science Co., Ltd). The water droplet contact angle

measured will be 7°. The low water droplet contact angle is indicative of the hydrophilic property of the coating.

[0140] Water resistance and Durability: The hydrophilic coating is subjected to a rubbing treatment with sponge in 10 reciprocations in water while applying a load of 1 kg. The amount of residual film is calculated from a change of weight before and after the rubbing treatment. The weight of the film after the rubbing treatment will be 97% of the initial weight.

[0141] Weather resistance: The hydrophilic coating is exposed in a chamber to a xenon arc lamp that is calibrated to mimic the sun spectral characteristics (Atlas Sun Test). The exposure is performed for 500 hours and evaluated with respect to hydrophilicity, water resistance and durability. The hydrophilic coating will exhibit the same properties before and after the exposure.

[0142] In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0143] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and

scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[0144] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

[0145] While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups.

[0146] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0147] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (*for example*, bodies of the appended claims) are generally intended as "open" terms (*for example*, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (*for example*, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (*for example*, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*for example*, " a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together,

etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*for example*, " a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0148] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0149] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for

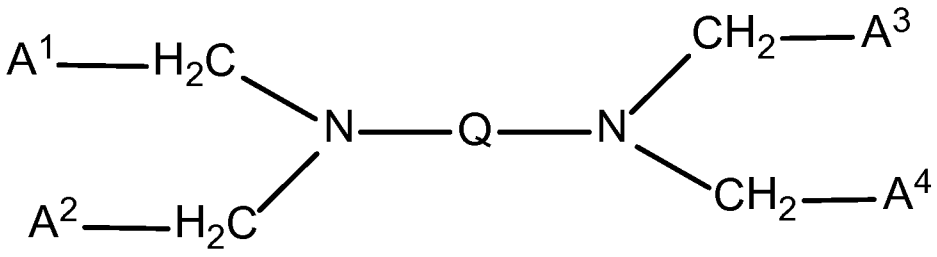
example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0150] Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

CLAIMS

What Is Claimed Is:

1. A compound of formula I:



(I)

wherein A^1 is -H, $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, $-N^+[Z\text{-}CH_3]_3.X^-$, $-O\text{-}C(=O)\text{-}COO^-.Na^+$, $-N^+(\text{-}CH_3)_2\text{-}Z\text{-}CH_3.X^-$, or salts thereof;

A^2 is -H, $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-O\text{-}C(=O)\text{-}COO^-.Na^+$, $-N^+(\text{-}CH_3)_2\text{-}Z\text{-}CH_3.X^-$, or salts thereof;

A^3 is $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-O\text{-}C(=O)\text{-}COO^-.Na^+$, $-N^+(\text{-}CH_3)_2\text{-}Z\text{-}CH_3.X^-$, or salts thereof;

A^4 is $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-O\text{-}Z\text{-}CH_3$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-O\text{-}C(=O)\text{-}COO^-.Na^+$, $-N^+(\text{-}CH_3)_2\text{-}Z\text{-}CH_3.X^-$, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent;

Q is $–C(=O)\text{-}$, $-CH_2\text{-}CH_2\text{-}$, $-CH_2\text{-}(CH_2)_k\text{-}CH_2\text{-}$, $-C(=O)\text{-}NH\text{-}C(=O)\text{-}$, or polyurea, where k is an integer from 1 to 10; and

X is Cl, Br, F, I, or OH, and

wherein at least one of A^1, A^2, A^3, and A^4 is hydrophilic, and at least one of A^1, A^2, A^3, and A^4 is hydrophobic.

2. The compound of claim 1, wherein A^1 is -H, $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, or $-O\text{-}Z\text{-}CH_3$.

3. The compound of claim 1 or claim 2, wherein A^2 is -H, $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, or $-O\text{-}Z\text{-}CH_3$.

4. The compound of any one of claims 1 to 3, wherein A^3 is $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, or $-O\text{-}Z\text{-}CH_3$.

5. The compound of any one of claims 1 to 4, wherein A^4 is $–N[CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, or $-O\text{-}Z\text{-}CH_3$.

6. The compound of claim 1, wherein:

A^1 is $-N[Z\text{-}CH_3]_2$ or $-O\text{-}Z\text{-}CH_3$;

A^2 is $-N[Z\text{-}CH_3]_2$ or $-O\text{-}Z\text{-}CH_3$;

A^3 is $–N[CH_2\text{-}N^+(CH_3)_3.Br^-]_2$ or $-N^+(Z\text{-}CH_3)_3.Br^-$;

A^4 is $–N[CH_2\text{-}N^+(CH_3)_3.Br^-]_2$ or $-N^+(Z\text{-}CH_3)_3.Br^-$; and

Q is $–C(=O)-$ or $-CH_2\text{-}(CH_2)_k\text{-}CH_2-$.

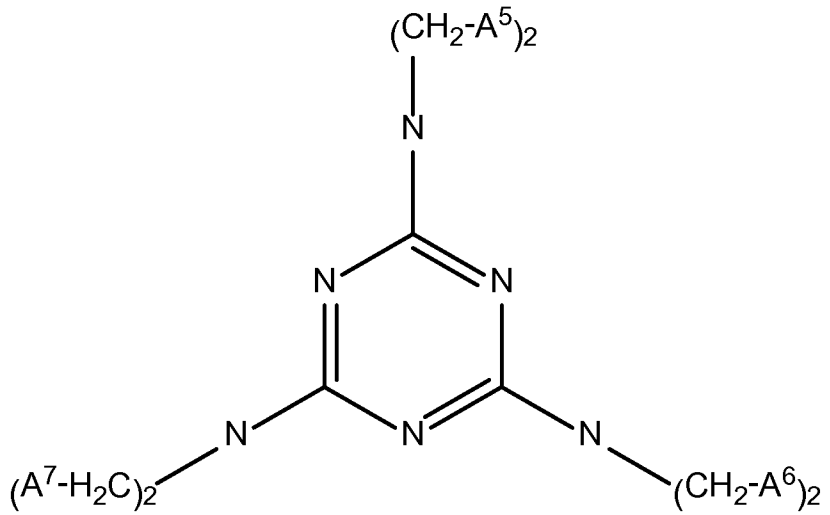
7. The compound of claim 1, wherein A^1 is $-N[Z\text{-}CH_3]_2$, A^2 is $-N[Z\text{-}CH_3]_2$, A^3 is $–N[CH_2\text{-}N^+(CH_3)_3.Br^-]_2$, A^4 is $–N[CH_2\text{-}N^+(CH_3)_3.Br^-]_2$, and Q is $–C(=O)-$.

8. The compound of claim 1, wherein A^1 is -O-C(=O)-$COO^-.Na^+$, A^2 is -O-Z-CH_3, A^3 is -O-C(=O)-$COO^-.Na^+$, A^4 is -O-Z-CH_3, and Q is –C(=O)- .

9. The compound of claim 1, wherein A^1 is -$N^+(-CH_3)_2$-Z-$CH_3.OH^-$, A^2 is -$N^+(-CH_3)_2$-Z-$CH_3.OH^-$, A^3 is -$N^+(-CH_3)_2$-Z-$CH_3.OH^-$, A^4 is -$N^+(-CH_3)_2$-Z-$CH_3.OH^-$, and Q is –C(=O)- .

10. The compound of claim 1, wherein A^1 is -$N^+(Z-CH_3)_3.Br^-$, A^2 is -O-Z-CH_3, A^3 is -$N^+(Z-CH_3)_3.Br^-$, A^4 is -O-Z-CH_3, and Q is –C(=O)- .

11. A compound of formula II:



(II)

wherein each A^5 is, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3.X^-$, -O-Z-CH_3, -$N^+(Z-CH_3)_3.X^-$, -O-C(=O)-$COO^-.Na^+$, or salts thereof;

each A^6 is, independently, -H, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X^-$

, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, or salts thereof;

each A^7 is, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^- , -O-Z-CH_3, -N^+(Z-CH_3)$_3$.X^-, -O-C(=O)-COO^-.Na^+, or salts thereof;

each Z is independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH and

wherein at least one of A^5, A^6, and A^7 is hydrophilic, and at least one of A^5, A^6, and A^7 is hydrophobic.

12. The compound of claim 11, wherein each A^5 is, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -N-(CH_2-CH_2-OH)$_2$, -NH-CH_2-CH_2-OH, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.

13. The compound of claim 11 or claim 12, wherein each A^6 is, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.

14. The compound of any one of claims 11 to 13, wherein each A^7 is, independently, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, or -O-Z-CH_3.

15. The compound of claim 11, wherein:

each A^5 is, independently, -N^+H_3.Br^- or –N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$;

each A^6 is, independently, -N[Z-CH_3]$_2$ or -O-Z-CH_3; and

each A^7 is, independently, $-N[Z\text{-}CH_3]_2$ or $-O\text{-}Z\text{-}CH_3$.

16. The compound of claim 11, wherein:

each A^5 is, independently, $-N^+(Z\text{-}CH_3)_3.X^-$ or $-SO_3H$;

each A^6 is, independently, $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$ or $-N(-CH_3)\text{-}Z\text{-}CH_3$; and

each A^7 is, independently, $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$ or $-N(-CH_3)\text{-}Z\text{-}CH_3$.

17. The compound of claim 11, wherein each A^5 is $-N(CH_2\text{-}CH_2\text{-}OH)_2$, each A^6 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, and each A^7 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$.

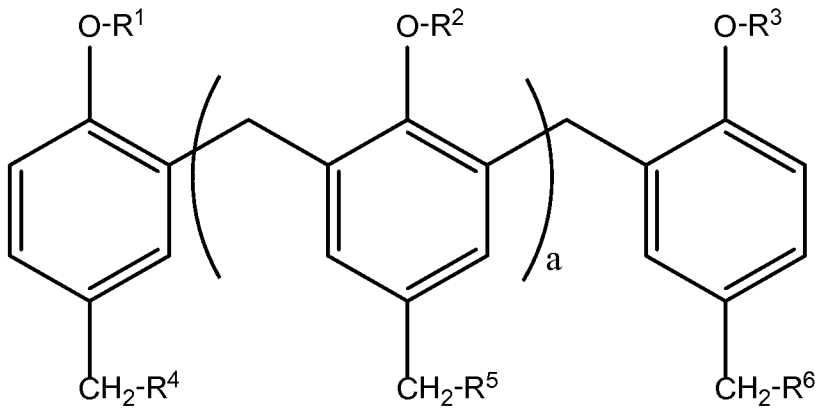
18. The compound of claim 11, wherein each A^5 is $-O\text{-}C(=O)\text{-}COO^-.Na^+$, each A^6 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, and each A^7 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$.

19. The compound of claim 11, wherein each A^5 is $-O\text{-}SO^-_3.Na^+$, each A^6 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, and each A^7 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$.

20. The compound of claim 11, wherein each A^5 is $-O\text{-}PO^{2-}_3.2Na^+$, each A^6 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$, and each A^7 is $-O\text{-}C(=O)\text{-}Z\text{-}CH_3$.

21. The compound of claim 11, wherein each A^5 is $-N^+(Z\text{-}CH_3)_3.OH^-$, each A^6 is $-N^+(Z\text{-}CH_3)_3.OH^-$, and each A^7 is $-N^+(Z\text{-}CH_3)_3.OH^-$.

22. A compound of formula III:



(III)

wherein

a is an integer from 1 to 10;

R^1 is $–CH_2-N(-CH_3)-Z-CH_3$, $-C(=O)-CH_2-CH_2-COOH$, $-C(=O)-CH_2-COOH$, $-SO_3H$, $-PO_3H_2$, $–CH_2-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$, $-CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-COO^-.Na^+$, or salts thereof;

each R^2 is, independently, $–CH_2-N(-CH_3)-Z-CH_3$, $-C(=O)-CH_2-CH_2-COOH$, $-C(=O)-CH_2-COOH$, $-SO_3H$, $-PO_3H_2$, $–CH_2-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$, $-CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-COO^-.Na^+$, or salts thereof;

R^3 is $–CH_2-N(-CH_3)-Z-CH_3$, $-C(=O)-CH_2-CH_2-COOH$, $-C(=O)-CH_2-COOH$, $-SO_3H$, $-PO_3H_2$, $–CH_2-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_3)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N[Z-CH_3]_2$, $-CH_2-CH(-OH)-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, $-CH_2-CH(-OH)-CH_2-N^+(CH_2-CH_2-OH)_3.X^-$, $-CH_2-CH(-OH)-CH_2-N^+(Z-CH_3)_3.X^-$, $-CH_2-COO^-.Na^+$, or salts thereof;

R^4 is $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N^+(Z-CH_3)_3.X^-$, $-Z-CH_3$, or salts thereof;

each R^5 is, independently, $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-O-SO_3H$, $-O-PO_3H_2$, $–N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N^+(Z-CH_3)_3.X^-$, $-Z-CH_3$, or salts thereof;

R^6 is -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N^+(Z-CH_3)$_3$.X^-, -Z-CH_3, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophilic, and at least one of R^1, R^2, R^3, R^4, R^5, and R^6 is hydrophobic.

23. The compound of claim 22, wherein R^1 is –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.

24. The compound of claim 22 or 23, wherein each R^2 is, independently, –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.

25. The compound of any one of claims 22 to 24, wherein R^3 is –CH_2-N(-CH_3)-Z-CH_3, -C(=O)-CH_2-CH_2-COOH, -C(=O)-CH_2-COOH, -SO_3H, -PO_3H_2, –CH_2-N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -CH_2-CH(-OH)-CH_2-N^+(CH_3)$_3$.Cl^-, or -CH_2-CH(-OH)-CH_2-N[Z-CH_3]$_2$.

26. The compound of any one of claims 22 to 25, wherein R^4 is -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-N^+(CH_3)$_3$.Br^-]$_2$, -N^+H_3.Br^-, or -N[Z-CH_3]$_2$,

27. The compound of any one of claims 22 to 26, wherein each R^5 is, independently, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.Br^-$]$_2$, -$N^+H_3.Br^-$, -N[Z-CH_3]$_2$.

28. The compound of any one of claims 22 to 27, wherein R^6 is -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, -O-SO_3H, -O-PO_3H_2, –N[CH_2-$N^+(CH_3)_3.Br^-$]$_2$, -$N^+H_3.Br^-$, -N[Z-CH_3]$_2$.

29. The compound of claim 22, wherein:

R^1 is –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$ or -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$;

each R^2 is –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$ or -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$;

R^3 is –CH_2-N[CH_2-$N^+(CH_3)_3.X^-$]$_2$ or -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.X^-$;

R^4 is -N(-CH_3)-Z-CH_3 or -N[Z-CH_3]$_2$;

each R^5 is -N(-CH_3)-Z-CH_3 or -N[Z-CH_3]$_2$; and

R^6 is -N(-CH_3)-Z-CH_3 or -N[Z-CH_3]$_2$.

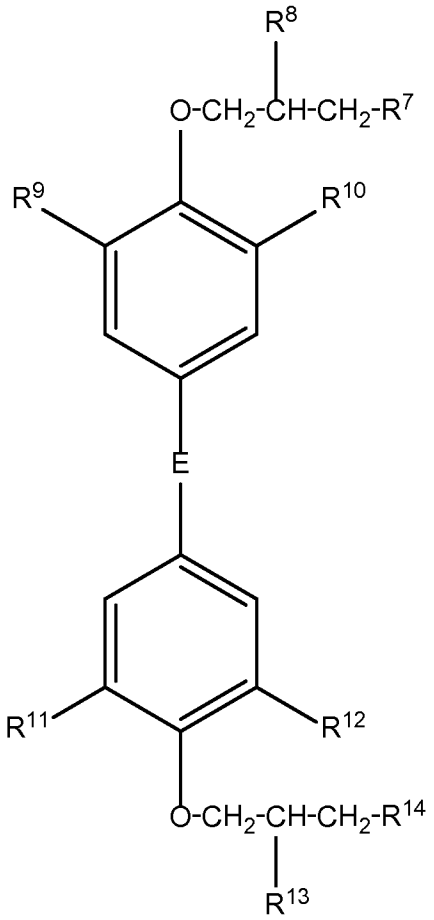
30. The compound of claim 22, wherein R^1 is -CH_2-$COO^-.Na^+$, each R^2 is -CH_2-$COO^-.Na^+$, R^3 is -CH_2-$COO^-.Na^+$, R^4 is -N[Z-CH_3]$_2$, each R^5 is -N[Z-CH_3]$_2$, and R^6 is -N[Z-CH_3]$_2$.

31. The compound of claim 22, wherein R^1 is -CH_2-$COO^-.Na^+$, each R^2 is -CH_2-$COO^-.Na^+$, R^3 is -CH_2-$COO^-.Na^+$, R^4 is -Z-CH_3, each R^5 is -Z-CH_3, and R^6 is -Z-CH_3.

32. The compound of claim 22, wherein R^1 is -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.Cl^-$, each R^2 is -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.Cl^-$, R^3 is -CH_2-CH(-OH)-CH_2-$N^+(CH_3)_3.Cl^-$, R^4 is -Z-CH_3, each R^5 is -Z-CH_3, and R^6 is -Z-CH_3.

33. The compound of claim 22, wherein R^1 is $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, each R^2 is $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, R^3 is $-CH_2-CH(-OH)-CH_2-N-(CH_2-CH_2-OH)_2$, R^4 is $-Z-CH_3$, each R^5 is $-Z-CH_3$, and R^6 is $-Z-CH_3$.

34. A compound of formula IV:



(IV)

wherein

R^7 is $-N(-CH_3)-Z-CH_3$, $-N[CH_2-N^+(CH_3)_3X^-]_2$, $-N^+(CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-N-(CH_2-CH_2-COOH)_2$, or salts thereof;

R^8 is $-OH$, $-O-C(=O)-Z-CH_3$, $-N(-CH_3)-Z-CH_3$, $-O-C(=O)-CH_2-CH_2-COOH$, $-O-C(=O)-CH_2-COOH$, $-N[CH_2-N^+(CH_3)_3.X^-]_2$, $-N^+H_3.X^-$, $-N[Z-CH_3]_2$, $-N^+(Z-CH_3)_3.X^-$, $-NH-CH_2-CH_2-OH$, $-N-(CH_2-CH_2-OH)_2$, $-N^+(CH_2-CH_2-OH)_3.X^-$, $-O-Z-CH_3$, or salts thereof;

R^9 is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{10} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{11} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{12} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, -CH_2-N-(CH_2-CH_2-OH)$_2$, -CH_2-N^+(CH_2-CH_2-OH)$_3$, -CH_2-O-Z-CH_3, -CH_2-N^+(Z-CH_3)$_3$.X^- , or salts thereof;

R^{13} is –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-N^+(CH_3)$_3$.X^-]$_2$, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3$.X^-, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -O-Z-CH_3, or salts thereof;

R^{14} is -N(-CH_3)-Z-CH_3, –N[CH_2-N^+(CH_3)$_3X^-$]$_2$, -N^+(CH_3)$_3$.X^-, -N^+H_3.X^-, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, -N-(CH_2-CH_2-OH)$_2$, -N^+(CH_2-CH_2-OH)$_3$.X^-, -N-(CH_2-CH_2-COOH)$_2$, or salts thereof;

E is -CH_2-, -C(CH_3)$_2$-, -S-, -S(=O)$_2$-, -S(=O)-, -CH(CCl_3)-, -C(Cl)$_2$-, -O-, or -C(F)$_2$-;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophilic, and at least one of R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, and R^{14} is hydrophobic.

35. The compound of claim 34, wherein R^7 is -N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3X^-]_2$, -$N^+(CH_3)_3.X^-$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$.

36. The compound of claim 34 or 35, wherein R^8 is –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3.X^-$, or -NH-CH_2-CH_2-OH.

37. The compound of any one of claims 34 to 36, wherein R^9 is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$.

38. The compound of any one of claims 34 to 37, wherein R^{10} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$.

39. The compound of any one of claims 34 to 38, wherein R^{11} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$.

40. The compound of any one of claims 34 to 39, wherein R^{12} is –H, -CH_2-O-C(=O)-Z-CH_3, -CH_2-N(-CH_3)-Z-CH_3, -CH_2-O-C(=O)-CH_2-CH_2-COOH, -CH_2-O-C(=O)-CH_2-COOH, -CH_2-N[Z-CH_3]$_2$, -CH_2-NH-CH_2-CH_2-OH, or -CH_2-N-(CH_2-CH_2-OH)$_2$.

41. The compound of any one of claims 34 to 40, wherein R^{13} is –OH, -O-C(=O)-Z-CH_3, -N(-CH_3)-Z-CH_3, -O-C(=O)-CH_2-CH_2-COOH, -O-C(=O)-CH_2-COOH, –N[CH_2-$N^+(CH_3)_3.X^-]_2$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -N^+(Z-CH_3)$_3.X^-$, or -NH-CH_2-CH_2-OH.

42. The compound of any one of claims 34 to 41, wherein R^{14} is -N(-CH_3)-Z-CH_3, –N[CH_2-$N^+(CH_3)_3X^-]_2$, -$N^+(CH_3)_3.X^-$, -$N^+H_3.X^-$, -N[Z-CH_3]$_2$, -NH-CH_2-CH_2-OH, or -N-(CH_2-CH_2-OH)$_2$.

43. The compound of claim 34, wherein R^7 is -$N^+(CH_3).Cl^-$, R^8 is -OH , R^9 is -CH_2-N^+(Z-CH_3)$_3.X^-$, R^{10} is -H, R^{11} is -CH_2-N^+(Z-CH_3)$_3.X^-$, R^{12} is –H, R^{13} is –OH, R^{14} is -$N^+(CH_3).Cl^-$; and E is -C(CH_3)$_2$-.

44. The compound of claim 34, wherein R^7 is –N(CH_2-CH_2-OH)$_2$, R^8 is -OH, R^9 is -CH_2-N^+(Z-CH_3)$_3.Cl^-$, R^{10} is -H, R^{11} is -CH_2-N^+(Z-CH_3)$_3.Cl^-$, R^{12} is –H, R^{13} is –OH, R^{14} is –N(CH_2-CH_2-OH)$_2$, and E is -C(CH_3)$_2$-.

45. The compound of claim 34, wherein R^7 is –N(CH_2-CH_2-$COO^-.Na^+$)$_2$, R^8 is -OH, R^9 is -CH_2-N^+(Z-CH_3)$_3.X^-$, R^{10} is -H, R^{11} is -CH_2-N^+(Z-CH_3)$_3.X^-$, R^{12} is –H, R^{13} is -OH, R^{14} is -N(CH_2-CH_2-$COO^-.Na^+$)$_2$, and E is -C(CH_3)$_2$-.

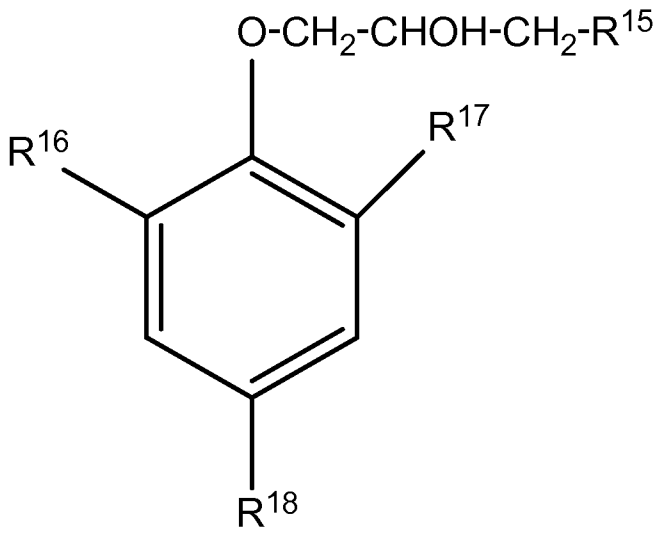
46. The compound of claim 34, wherein R^7 is -$N^+(CH_3)_3.Cl^-$, R^8 is -O-C(=O)-Z-CH_3, R^9 is -H, R^{10} is -H , R^{11} is -H, R^{12} is –H, R^{13} is -O-C(=O)-Z-CH_3, R^{14} is -$N^+(CH_3)_3.Cl^-$, and E is -C(CH_3)$_2$-.

47. The compound of claim 34, wherein R^7 is –N(CH_2-CH_2-OH)$_2$, R^8 is -N^+(Z-CH_3)$_3.X^-$, R^9 is -H, R^{10} is -H , R^{11} is -H, R^{12} is –H, R^{13} is -N^+(Z-CH_3)$_3.X^-$, R^{14} is –N(CH_2-CH_2-OH)$_2$, and E is -C(CH_3)$_2$-.

48. The compound of claim 34, wherein R^7 is –N(CH_2-CH_2-$COO^-.Na^+$)$_2$, R^8 is -N^+(Z-CH_3)$_3.X^-$, R^9 is -H, R^{10} is -H , R^{11} is -H, R^{12} is –H, R^{13} is -N^+(Z-CH_3)$_3.X^-$, R^{14} is -N(CH_2-CH_2-$COO^-.Na^+$)$_2$, and E is -C(CH_3)$_2$-.

49. The compound of claim 34, wherein R^7 is $–N(Z\text{-}CH_3)_2$, R^8 is –OH, R^9 is $-CH_2\text{-}N(Z\text{-}CH_3)_2$, R^{10} is $–CH_2\text{-}N\text{-}[CH_2\text{-}CH_2\text{-}OH]_2$, R^{11} is $–CH_2\text{-}N\text{-}[Z\text{-}CH_3]_2$, R^{12} is $–CH_2\text{-}N(CH_2\text{-}CH_2\text{-}OH)_2$, R^{13} is –OH, R^{14} is $–N(CH_2\text{-}CH_2\text{-}OH)_2$, and E is $-C(CH_3)_2-$.

50. A compound of formula V:



(V)

wherein

R^{15} is $-N(-CH_3)\text{-}Z\text{-}CH_3$, $–N[CH_2\text{-}N^+(CH_3)_3X^-]_2$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N^+(CH_3)_3.X^-$,

$-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-N\text{-}(CH_2\text{-}CH_2\text{-}COOH)_2$, or salts thereof;

R^{16} is –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-CH_2\text{-}O\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-$, $-CH_2\text{-}N^+(CH_3)_3.X^-$, $-CH_2\text{-}O\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}N(Z\text{-}CH_3)_2$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}COOH)_2$, or salts thereof;

R^{17} is –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}$

$(CH_2\text{-}CH_2\text{-}OH)_2$, $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-CH_2\text{-}O\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-$, $-CH_2\text{-}O\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}N(Z\text{-}CH_3)_2$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}COOH)_2$, or salts thereof;

R^{18} is $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3.X^-$, $-CH_2\text{-}O\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N^+(Z\text{-}CH_3)_3.X^-$, $-CH_2\text{-}O\text{-}CH_2\text{-}CHOH\text{-}CH_2\text{-}N(Z\text{-}CH_3)_2$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}COOH)_2$, or salts thereof;

each Z is, independently, C_1-C_{25} alkylene, C_1-C_{25} substituted alkylene, C_6-C_{25} arylene, C_6-C_{25} substituted arylene, C_2-C_{25} alkenylene, C_2-C_{25} substituted alkenylene, C_2-C_{25} alkynylene, C_2-C_{25} substituted alkynylene, or absent; and

X is Cl, Br, F, I, or OH, and

wherein at least one of R^{15}, R^2, R^3, and R^4 is hydrophilic, and at least one of R^{15}, R^{16}, R^{17}, and R^{18} is hydrophobic.

51. The compound of claim 50, wherein R^{15} is $-N(-CH_3)\text{-}Z\text{-}CH_3$, $-N[CH_2\text{-}N^+(CH_3)_3X^-]_2$, $-N^+(Z\text{-}CH_3)_3.X^-$, $-N^+H_3.X^-$, $-N[Z\text{-}CH_3]_2$, $-NH\text{-}CH_2\text{-}CH_2\text{-}OH$, or $-N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$.

52. The compound of claim 50 or 51, wherein R^{16} is –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, or $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3$.

53. The compound of any one of claims 50 to 52, wherein R^{17} is –H, $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}N[Z\text{-}CH_3]_2$, $-CH_2\text{-}NH\text{-}CH_2\text{-}CH_2\text{-}OH$, $-CH_2\text{-}N\text{-}(CH_2\text{-}CH_2\text{-}OH)_2$, or $-CH_2\text{-}N^+(CH_2\text{-}CH_2\text{-}OH)_3$.

54. The compound of any one of claims 50 to 53, wherein R^{18} is $-CH_2\text{-}O\text{-}C(=O)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}N(-CH_3)\text{-}Z\text{-}CH_3$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}CH_2\text{-}COOH$, $-CH_2\text{-}O\text{-}C(=O)\text{-}CH_2\text{-}$

COOH, $-CH_2-N[Z-CH_3]_2$, $-CH_2-NH-CH_2-CH_2-OH$, $-CH_2-N-(CH_2-CH_2-OH)_2$, or $-CH_2-N^+(CH_2-CH_2-OH)_3$.

55. The compound of claim 50, wherein:

R^{15} is $-N^+(Z-CH_3)_3.X^-$ or $-N^+(H_3).OH^-$;

R^{16} is $-N[Z-CH_3]_2$ or $-O-Z-CH_3$;

R^{17} is $-N[Z-CH_3]_2$ or $-O-Z-CH_3$; and

R^{18} is $-N[Z-CH_3]_2$ or $-O-Z-CH_3$.

56. The compound of claim 50, wherein R^{15} is $-N^+(CH_3)_3.Cl^-$, R^{16} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, R^{17} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$,and R^{18} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$.

57. The compound of claim 50, wherein R^{15} is $-N^+(Z-CH_3)_3.Cl^-$, R^{16} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$, R^{17} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$,and R^{18} is $-CH_2-O-CH_2-CHOH-CH_2-N(Z-CH_3)_2$.

58. The compound of claim 50, wherein R^{15} is $-N^+(CH_3)_3.Cl^-$, R^{16} is $-CH_2-N^+(CH_3)_3.Cl^-$, R^{17} is $-CH_2-N^+(Z-CH_3)_3.Cl^-$, and R^{18} is $-CH_2-N^+(Z-CH_3)_3.Cl^-$.

59. A composition comprising any one or more of the compounds of any one of claims 1 to 58.

60. The composition of claim 59, wherein the composition is a decorative coating, an industrial coating, a protective coating, a self-cleaning coating, a biocidal coating, a skin care product, a demulsifying agent, a phase transfer catalyst, a dispersant, or a defoamer.

61. A method of making a compound of formula I, the method comprising:

contacting any one of urea, biuret, or alkylene diamine with formaldehyde to form a hydroxymethyl compound; and

contacting the hydroxymethyl compound with a dimethyl alkyl amine.

62. The method of claim 61, wherein the urea, biuret, or alkylene diamine is contacted with formaldehyde in a molar ratio from about 1:2 to about 1:6.

63. The method of claim 61, wherein contacting any one of urea, biuret, or alkylene diamine with formaldehyde comprises heating to a temperature of about 50 °C to about 90 °C for about 2 hours to about 6 hours in the presence of a basic catalyst.

64. The method of claim 61, wherein contacting the hydroxymethyl compound with the dimethyl alkyl amine comprises heating to a temperature of about 20 °C to about 40 °C for about 2 hours to about 6 hours.

65. A method of making a compound of formula II, the method comprising:

contacting melamine with formaldehyde to form a hydroxymethyl melamine derivative;

contacting the hydroxymethyl melamine derivative with diethanolamine to form a diethanol melamine derivative; and

contacting the diethanol melamine derivative with an alkyl halide.

66. The method of claim 65, wherein contacting melamine with formaldehyde comprises heating to a temperature of about 50 °C to about 90 °C for about 2 hours to about 6 hours.

67. The method of claim 65, wherein contacting the hydroxymethyl melamine derivative with diethanolamine comprises heating to a temperature of about 20 °C to about 40 °C for about 2 hours to about 6 hours.

68. The method of claim 65, wherein contacting the diethanol melamine derivative with an alkyl halide comprises heating to a temperature of about 30 °C to about 60 °C for about 2 hours to about 6 hours.

69. A method of making a compound of formula III, the method comprising:

contacting novolac with epichlorohydrin to form a novolac-chlorohydrin derivative;

contacting the novolac-chlorohydrin derivative with any one of diethanolamine or triethylamine to form a novolac derivative; and

contacting the novolac derivative with an alkyl chloride.

70. The method of claim 69, wherein contacting novolac with epichlorohydrin comprises heating to a temperature of about 50 °C to about 90 °C for about 2 hours to about 6 hours.

71. The method of claim 69, wherein contacting the novolac-chlorohydrin derivative with any one of diethanolamine or triethylamine comprises heating to a temperature of about 50 °C to about 90 °C for about 1 hour to about 3 hours.

72. A method of making a compound of formula IV, the method comprising:

contacting a bisphenol compound with epichlorohydrin and formaldehyde to form a tetramethylol bisphenol derivative;

contacting the tetramethylol bisphenol derivative with any one of the following: a mixture of trimethylamine and N,N,N,-trialkyl amine, a mixture of diethanol amine and N,N,N,-trialkyl amine, and a mixture of disodium propionate amine and N,N,N,-trialkyl amine.

73. The method of claim 72, wherein the mixture of trimethylamine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of trimethylamine and N,N,N,-trialkyl amine.

74. The method of claim 72, wherein the mixture of diethanol amine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of diethanol amine and N,N,N,-trialkyl amine.

75. The method of claim 72, wherein the mixture of disodium propionate amine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of disodium propionate amine and N,N,N,-trialkyl amine.

76. The method of claim 72, wherein contacting the tetramethylol bisphenol derivative with the mixture of trimethylamine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 ^{o}C to about 60 ^{o}C for about 1 hour to about 6 hours.

77. The method of claim 72, wherein contacting the tetramethylol bisphenol derivative with the mixture of diethanol amine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 ^{o}C to about 60 ^{o}C for about 1 hour to about 6 hours.

78. The method of claim 72, wherein contacting the tetramethylol bisphenol derivative with the mixture of disodium propionate amine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 ^{o}C to about 60 ^{o}C for about 1 hour to about 6 hours.

79. A method of making a compound of formula V, the method comprising:

contacting a resol with epichlorohydrin to form a resol-chlorohydrin derivation; and

contacting the resol-chlorohydrin derivative with any one of the following: a mixture of triethylamine and N,N,N,-trialkyl amine, a mixture of diethanol amine and

N,N,N,-trialkyl amine, a mixture of disodium propionate amine and N,N,N,-trialkyl amine.

80. The method of claim 79, wherein the mixture of trimethylamine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of trimethylamine and N,N,N,-trialkyl amine.

81. The method of claim 79, wherein the mixture of diethanol amine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of diethanol amine and N,N,N,-trialkyl amine.

82. The method of claim 79, wherein the mixture of disodium propionate amine and N,N,N,-trialkyl amine comprises a mixture having equimolar amounts of disodium propionate amine and N,N,N,-trialkyl amine.

83. The method of claim 79, wherein contacting the resol-chlorohydrin derivative with the mixture of trimethylamine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 °C to about 60 °C for about 1 hour to about 6 hours.

84. The method of claim 79, wherein contacting the resol-chlorohydrin derivative with the mixture of diethanol amine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 °C to about 60 °C for about 1 hour to about 6 hours.

85. The method of claim 79, wherein contacting the resol-chlorohydrin derivative with the mixture of disodium propionate amine and N,N,N,-trialkyl amine comprises heating to a temperature of about 30 °C to about 60 °C for about 1 hour to about 6 hours.

86. A method of coating a substrate, the method comprising applying a coating composition to the substrate, wherein the coating composition comprises one or more compounds of formula I-V.

87. The method of claim 86, wherein the coating composition further comprises a binder, a solvent, a pigment, a coalescing agent, a rheology modifier, a plasticizer, or any combination thereof.

88. The method of claim 86, wherein applying the coating composition to the substrate comprises applying the coating composition by brushing, dipping, spraying, or rolling, or any combination thereof.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/072619

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C07C 215/14 (2014.01)
USPC - 564/60
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - C07C 211/63, 215/14, 215/40, 229/16, 275/14, 275/62 (2014.01)
USPC - 560/169, 171; 564/38, 59, 60, 291, 292

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - C07C 211/63, 215/14, 215/40, 229/16, 275/14, 275/62 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Orbit, PubChem, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,884,557 B2 (KASAI et al) 26 April 2005 (26.04.2005) entire document	1-3, 6-10, 61-64
A	US 4,883,826 A (MARUGG et al) 28 November 1989 (28.11.1989) entire document	1-3, 6-10, 61-64
A	US 2012/0164288 A1 (MILLER) 28 June 2012 (28.06.2012) entire document	1-3, 6-10, 61-64
A	EP 0 279 475 A2 (GREEN et al) 24 August 1988 (24.08.1988) entire document	1-3, 6-10, 61-64
A	US 3,957,524 A (DOUGHTY et al) 18 May 1976 (18.05.1976) entire document	1-3, 6-10, 61-64

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 2014	12 MAY 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/072619

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4, 5, 14, 25-28, 37-42, 53, 54, 59, 60
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Extra Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3, 6-10, 61-64

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/072619

<Continued from Box III: Observations where unity of invention is lacking>

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I: Claims 1-3, 6-10, and 61-64 are drawn to compounds of formula I, and methods of making a compound thereof.

Group II: Claims 11-13, 15-21, and 65-68 are drawn to compounds of formula II, and methods of making a compound thereof.

Group III: Claims 22-24, 29-33, and 69-71 are drawn to compounds of formula III, and methods of making a compound thereof.

Group IV: Claims 34-36, 43-49, and 72-78 are drawn to compounds of formula IV, and methods of making a compound thereof.

Group V: Claims 50-52, 55-58, and 79-85 are drawn to compounds of formula V, and methods of making a compound thereof.

Group VI+: Claims 86-88 are drawn to a method of coating a substrate.

Group VI+ is restricted to a method of coating a substrate, the method comprising applying a coating composition to the substrate, wherein the coating composition comprises one or more compounds of formula I-V, wherein in an exemplary election the coating composition comprises a compound of formula I. Applicant is invited to elect additional compositions to be searched in a specific combination for each formula by paying additional fees for each election. Additional inventions will be searched upon the payment of additional fees. Applicants must specify the claims that read on any elected inventions. Failure to clearly identify how any paid additional invention fees are to be applied.to the "+" group(s) will result in only the first claimed invention to be searched/examined.

The inventions listed in Groups I through VI+ do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, compounds of formula I, are not present in Groups II through VI+; the special technical features of Group II, compounds of formula II, are not present in Groups I and III through VI+; the special technical features of Group III, compounds of formula III, are not present in Groups I, II, and IV through VI+; the special technical features of Group IV, compounds of formula IV, are not present in Groups I through III, V, and VI+; the special technical features of Group V, compounds of formula V, are not present in Groups I through IV and VI+; and the special technical features of Group VI+, methods of coating a substrate, are not present in Groups I through V.

The Group VI+ coating compositions do not share a significant structural element responsible for coating the substrate, requiring selection of alternatives for the presence of "one or more compounds of formula I-V".

The Groups I through VI+ share the technical features of a compound wherein at least one of the substituents is hydrophilic, and at least one of the substituents is hydrophobic; a phenol derivative having the core structure of formula III, IV, or V, comprising a -CH2-CH (OH)-CH2-Rx group; methods of making compounds comprising reacting a precursor with formaldehyde or epichlorohydrin, forming an intermediate, and contacting said intermediate with N,N,N-trialkylamine and/or diethanolamine, trimethylamine, or disodium propionate; and a method of coating a substrate, the method comprising applying a coating composition to the substrate, wherein the coating composition comprises one or more of the compounds thereof. However, these shared technical features do not represent a contribution over the prior art.

Specifically, US 2012/0164288 A1 to Miller teaches a compound wherein at least one of the substituents is hydrophilic, and at least one of the substituents is hydrophobic (Para. [0007], ...a dye compound is provided including a hydrophilic dye moiety; and a hydrophobic moiety bonded to the hydrophilic dye moiety through a linker moiety...); and a method of coating a substrate, the method comprising applying a coating composition to the substrate, wherein the coating composition comprises one or more of the compounds thereof (Para. [0009], ...method also includes contacting a substrate and the dye composition for a time period sufficient to covalently bond at least a portion of the plurality of the dye compounds to the substrate, prior to exposing).

Additionally, EP 0 279 475 A2 to Green et al. teach a phenol derivative having the core structure of formula IV, comprising a -CH2-CH (OH)-CH2-N+(CH3)3X- group, wherein R7 is -N+CH3)3X-; R8 is -OH; R9 is -H; R10 is -H; R11 is H; R12 is -H; and X is Cl (Pg. 4 Lns. 5-23, Example 1, 2-Hydroxy-3-(4-benzoylphenoxy)-N,N,N-trimethyl-1-propanaminium chloride...).

Further, US 4,883,826 A to Marugg et al. teach a method of making compounds comprising reacting a precursor with formaldehyde or diethanolamine (Col. 1 Lns. 50-55, ...condensate of a phenolic compound, formaldehyde, and a mixture of diethimolamine and at least one other alkanolamine...; Col. 3 Lns. 61-64, the formaldehyde is added, with stirring, to the mixture of phenolic compound and alkanolamines slowly in order to control the exotherm of the reaction...).

Moreover, US 3,957,524 A to Doughty et al. teach a method of making compounds comprising reacting a precursor with epichlorohydrin, forming an intermediate, and contacting said intermediate with N,N,N-trialkylamine and/or trimethylamine (Col. 1 Lns. 10-12, ...quaternary amines formed from the reaction of an alkyl phenol, epichlorohydrin and trimethylamine as the cation active emulsifier; Col. 3 Lns. 18-26, alkyl phenol, methanol, water and epichlorohydrin are added together and stirred well. The four components form a clear solution. The trialkylamine is then added, and the temperature kept between 45°C. and 65°C. for about I to 8 hours. The resultant product when using trimethylamine and triethylamine is 3-(dodecyl phenoxy)-2 hydroxypropyl trimethyl ammonium chloride and 3-(dodecyl phenoxy)-2 hydroxypropyl triethyl ammonium chloride, respectively...).

Since none of the special technical features of the Groups I through VI+ inventions are found in more than one of the inventions, unity is lacking.

<End Box III: Observations where unity of invention is lacking>