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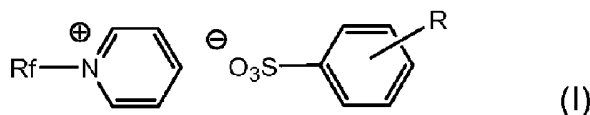
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(54) Title: FLUORINATED CATIONIC SURFACTANT



(57) Abstract: A composition comprising a fluorinated pyridinium cationic compound of formula (I) wherein R<sub>f</sub> is R<sup>1</sup>(CH<sub>2</sub>CH<sub>2</sub>)<sub>n</sub>-, R<sup>1</sup> is a C<sub>7</sub> to C<sub>20</sub> perfluoroalkyl group interrupted by at least one catenary oxygen atom, each oxygen bonded to two carbon atoms, n is an integer of 1 to 3, and R is H, C<sub>1</sub> to C<sub>5</sub> linear or branched alkyl, or C<sub>1</sub> to C<sub>5</sub> linear or branched alkoxy, having surfactant properties for lowering surface tension in an aqueous medium or solvent medium, and for use as a foaming agent.

WO 2011/046796 A1

TITLE**FLUORINATED CATIONIC SURFACTANT**FIELD OF THE INVENTION

This invention relates to a fluorinated pyridinium cationic compound  
5 for use as a surfactant or foaming agent for lowering surface tension in an aqueous medium or solvent medium.

BACKGROUND OF THE INVENTION

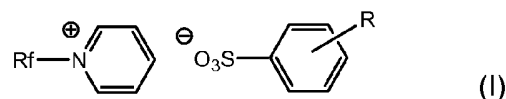
Fluorinated cationic compounds such as perfluoroalkyl quaternary ammonium derivatives are known in art, which have a saturated  
10 perfluoroalkyl terminal chain. For example, fluorinated cationic compounds disclosed in U.S. Patent 4,836,958 contain such a perfluoroalkyl terminal chain group having up to 18 carbon atoms. Commercially available fluorinated pyridinium cationic surfactants usually contain a saturated perfluoroalkyl terminal chain of at least 8 or more  
15 carbons. One skilled in the art expects that a shorter perfluoroalkyl chain, or one interrupted with a non-fluorinated atom, would have decreased performance because the individual perfluoroalkyl chains are not maintained in a parallel configuration.

Therefore, it is desirable to provide fluorinated surfactants having  
20 interrupted fluorinated chains while still providing equivalent or even better surface properties compared to those fluorinated surfactants which contain longer uninterrupted fully fluorinated perfluorinated chains.

It has been discovered in this invention that a fluorinated pyridinium cationic surfactant having a fluorinated terminal chain interrupted by  
25 oxygen provides desirable surface effects in a variety of applications and is particularly useful in oil field and gas field applications.

SUMMARY OF THE INVENTION

The present invention comprises a compound of formula (I)



wherein,

R<sub>f</sub> is R<sup>1</sup>(CH<sub>2</sub>CH<sub>2</sub>)<sub>n</sub>-,

R<sup>1</sup> is a C<sub>7</sub> to C<sub>20</sub> perfluoroalkyl group interrupted by at least one catenary oxygen atom, each oxygen bonded to two carbon atoms,

5 n is an integer of 1 to 3, and

R is H, C<sub>1</sub> to C<sub>5</sub> linear or branched alkyl, or C<sub>1</sub> to C<sub>5</sub> linear or branched alkoxy.

The present invention further comprises a method of modifying surface effects of an aqueous medium or solvent medium comprising  
10 contacting the medium with a compound of formula (I) as described above.

#### DETAILED DESCRIPTION

As used herein, the term “surfactant” means surface-active agent, which refers to a substance which, even at low concentrations, effectively  
15 lowers the surface tension of a medium containing the surfactant by selective adsorption on the interface. A surfactant can be a pure chemical compound or a mixture of homologues or different chemical compounds.

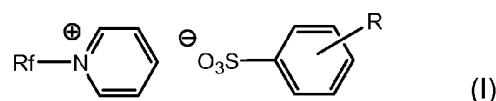
The term “drill fluids” as used herein means those liquids that are added to a well or well bore penetrating a subterranean zone containing  
20 hydrocarbon or gas prior to or during a drilling operation. Examples can include water, brine, solvent, hydrocarbons, surfactants, oils, kerosene, fracturing fluids, stimulating fluids, oil-based drill muds, clay stabilizers, treatment fluids, and mixtures thereof.

The term “well fluids” as used herein means those liquids that occur  
25 in or are added to a well or well bore penetrating a subterranean zone containing hydrocarbon or gas. Examples can include drill fluids, water, brine, solvent, hydrocarbons, surfactants, oils, kerosene, fracturing fluids, stimulating fluids, oil-based drill muds, clay stabilizers, treatment fluids, and mixtures thereof.

30 The term “liquid treatment stream or gas treatment stream” as used herein means a liquid composition or gas composition, or a combination thereof, injected into a well penetrating a subterranean zone containing

hydrocarbon or gas, or into a well bore area, in the operation of extracting the hydrocarbon or gas. Examples can include steam, drill fluids, well fluids, stimulating fluids, water, brine, solvent, hydrocarbons, surfactants, fracturing fluids, oil-based drill muds, clay stabilizers, treatment fluids, and mixtures thereof.

The present invention comprises a fluorinated pyridinium cationic compound of the formula (I)



wherein,

Rf is  $R^1(CH_2CH_2)_n$ ,

$R^1$  is a C<sub>7</sub> to C<sub>20</sub> perfluoroalkyl group interrupted by at least one catenary oxygen atom, each oxygen bonded to two carbon atoms,

n is an integer of 1 to 3, and

R is H, C<sub>1</sub> to C<sub>5</sub> linear or branched alkyl, or C<sub>1</sub> to C<sub>5</sub> linear or branched alkoxy.

The perfluoroalkyl group contains at least one oxygen atom, but can contain from 1 to 19 oxygen atoms. Each oxygen atom is catenated between two carbon atoms.

Preferred compounds of formula (I) are those wherein n is 1 or 2. Also preferred are those wherein the perfluoroalkyl contains 1 to 15 oxygen atoms, more preferably 1 to 10 oxygen atoms, and more preferably 1 to 5 oxygen atoms, and even more preferred 1 to 3 oxygen atoms. Other preferred embodiments of formula (I) are those wherein R is hydrogen, methyl, ethyl, methoxy or ethoxy.

The compounds of formula (I) are prepared by the reaction of a pyridine with a fluorinated iodide followed by reaction of the resulting product with an arylsulfonic acid, typically in a solvent such as alcohol. One example of such a preparation is detailed as follows. The fluorinated iodides, such as compound C<sub>3</sub>F<sub>7</sub>O(CF<sub>2</sub>CF<sub>2</sub>)<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>I, is prepared by

allowing a fluorinated ether iodide such as  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{I}$ , to react with ethylene. The resulting product of  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{I}$  then is then contacted with pyridine under nitrogen. The reaction is allowed to reflux at about 80 °C for several hours, for example 20 hours. The product is  
5 isolating using conventional techniques. The above product  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{N}^+(\text{C}_5\text{H}_5)\text{I}^-$ , typically in an alcohol solvent, is then contacted under an inert gas, such as nitrogen, with heating to about 60°C. with a solution of arylsulfonic acid, such as p-toluenesulfonic acid in alcohol. The temperature is maintained for several hours, for example 80  
10 hours until  $\text{CH}_3\text{I}$  can no longer be detected by GC in the distillate, while additional alcohol is added periodically to replenish the distilled solvent. The alcohol is then evaporated off to yield the product as  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{N}^+(\text{C}_5\text{H}_5)\text{p-CH}_3\text{C}_6\text{H}_4\text{SO}_3^-$  which is characterized by NMR. The resulting product is then usually dissolved in methanol to  
15 obtain a 50% solution, and neutralized to a pH of  $5.5 \pm 0.5$  with 3.5% NaOH aqueous solution.

The surfactants comprising the fluorinated pyridinium cationic compounds of formula (I) are suitable for use in many applications, such as in coatings, oil/gas fields, fire fighting, polymerization, surface treatment  
20 and protection, agriculture, textiles, carpet, hard surface treatment and protections such as in flooring, stone and tiles, photovoltaic materials, and in automotive, herbicides, printing, paper and leather industries.

In one embodiment of the present invention the compound of formula (I) is useful as a surfactant to affect the surface tension or other  
25 surface properties of an aqueous medium or solvent medium. Suitable media include water, a coating composition, latex, polymer, floor finish, fire fighting agent, ink, emulsifying agent, foaming agent, release agent, repellency agent, flow modifier, film evaporation inhibitor, wetting agent, penetrating agent, cleaner, grinding agent, electroplating agent, corrosion  
30 inhibitor, etchant solution, soldering agent, dispersion aid, microbial agent, pulping aid, rinsing aid, polishing agent, personal care composition, drying agent, antistatic agent, floor polish, or bonding agent. This embodiment is useful to affect the surface tension and other surface properties of the

medium, or of a substrate to which the medium is applied. Types of surface behavior which can be altered using the compound of the present invention include, for example, wetting, penetration, spreading, leveling, flowing, emulsifying, dispersing, repelling, releasing, lubricating, etching, bonding, and stabilizing.

The above fluorinated pyridinium cationic compounds of Formula (I) are suitable for use as surfactants to lower surface tension in a medium. The resulting surface tension values in a medium are less than about 25 milli-newtons per meter, preferably less than about 20 milli-newtons per meter, more preferably less than about 19 milli-newtons per meter at a concentration of the surfactant of less than about 0.5 % by weight. Often such reduced surface tension is obtained at a concentration of less than about 0.2 % by weight, or less than about 0.1 % by weight. The surfactant is characterized by its efficiency in lowering the surface tension at low concentrations by selective adsorption on the interface determined by the amphiphilic nature of the surfactant. The term "amphiphilic" means attraction to two different kinds of media. Surfactants usually comprise a water-soluble hydrophilic part and a water-insoluble hydrophobic part.

The present invention further comprises a method of modifying surface effects of an aqueous medium or solvent medium comprising contacting the medium with a compound of formula (I). One such surface effect is lowering surface tension of a medium by contacting the medium with a fluorinated pyridinium cationic compound of formula (I). Examples of other surface behavior alteration include improvements in the properties of surface tension, wetting, penetration, spreading, leveling, flowing, emulsifying, stabilizing of dispersions in liquids, repellency, releasing, lubricating, etching, and bonding. Any of a wide variety of media is suitable for use in the method of the present invention. Typically the medium is an aqueous liquid or a solvent as detailed above.

Examples of such applications where low surface tension is required include coating compositions and aqueous and non-aqueous cleaning products, each for glass, wood, metal, brick, concrete, cement, natural and synthetic stone, tile, synthetic flooring, laminates, paper, textile

materials, linoleum and other plastics, resins, natural and synthetic rubbers, fibers and fabrics, and paints; polymers; and waxes, finishes, leveling and gloss agents for floors, furniture, shoes, inks, and automotive care. Wetting agent applications include wetting agents for compositions  
5 containing herbicides, fungicides, weed killers, hormone growth regulators, parasiticides, insecticides, germicides, bactericides, nematocides, microbiocides, defoliants or fertilizers, therapeutic agents, antimicrobials, fluorochemical blood substitutes, textile treatment baths, and fiber spin finishes. Applications in personal care products include shampoos,  
10 conditioners, creme rinses, cosmetic products for the skin (such as therapeutic or protective creams and lotions, oil and water repellent cosmetic powders, deodorants and antiperspirants), nail polish, lipstick, and toothpaste. Further applications include fabric care products (such as stain pretreatments and/or stain removers for clothing, carpets and  
15 upholstery), and laundry detergents. Other applications include rinse-aids (for car washes and in automatic dishwashers), for oil well treatments (including drilling muds and additives to improve tertiary oil well recovery), extreme pressure lubricants, lubricating cutting oil to improve penetration times, writing inks, printing inks, photography developer solutions,  
20 emulsions for fighting forest fires, dry chemical fire extinguishing agents, aerosol-type fire extinguishers, thickening agents to form gels for solidifying or encapsulating medical waste, photoresists, developers, cleaning solutions, etching compositions, developers, polishers, and resist inks in the manufacturing, processing, and handling of semiconductors  
25 and electronics. The surfactants of formula (I) can be incorporated into products that function as antifogging agents for glass surfaces and photography films, and as antistatic agents for magnetic tapes, phonograph records, floppy disks, disk drives, rubber compositions, PVC, polyester film, and photography films, and as surface treatments for optical  
30 elements (such as glass, plastic, or ceramics). Other applications are in emulsifying agents, foaming agents, release agents, repellency agents, flow modifiers, film evaporation inhibitors, wetting agents, penetrating agents, cleaners, grinding agents, electroplating agents, corrosion

inhibitors, soldering agents, dispersion aids, microbial agents, pulping aids, rinsing aids, polishing agents, drying agents, antistatic agents, antiblocking agents, bonding agents, and oil field chemicals.

Suitable media include a coating composition, latex, polymer, floor  
5 finish, fire fighting agent, water, saline solution, ink, emulsifying agent, foaming agent, release agent, repellency agent, flow modifier, film evaporation inhibitor, wetting agent, penetrating agent, cleaner, grinding agent, electroplating agent, corrosion inhibitor, etchant solution, soldering agent, dispersion aid, microbial agent, pulping aid, rinsing aid, polishing  
10 agent, personal care composition, drying agent, antistatic agent, floor polish, or bonding agent.

In another embodiment of the present invention the compound of the present invention is useful in gas and oil field applications. Herein a hydrocarbon is either a gas or oil product which is produced or recovered  
15 from a subterranean zone. A well or well bore is drilled and created to penetrate such a hydrocarbon containing subterranean zone. The surfactant composition of the present invention is useful to modify and improve the wettability and surface conditions, such as the surface tension of the subterranean formation around the well bore, and is also useful to  
20 improve the permeability and flow rate to enhance oil well or gas well recovery and productivity.

A compound of formula (I) acts as a surfactant or foaming agent for oil field and gas field applications. The compound of formula (I) is typically used in an aqueous medium selected from the group consisting of water,  
25 saline solution, KCl solution, HCl solution, hydrocarbon, halocarbon, drill fluids, well fluids, liquid treatment stream, gas treatment stream, and a mixture thereof, is used as a surfactant or foaming fluid. The compound of formula (I) is useful as an additive in drill fluids, well fluids, and other treatment fluids for subterranean formations, to enhance gas or oil  
30 recovery by altering surface tension, wettability, or viscosity of the fluids, oils, condensates, and muds employed or encountered in such operations. The surfactant can be used for foaming porous rock or soil medium of a subterranean formation, or for other known well or well bore treatments.

The present invention provides a surfactant or foaming fluid which comprises the fluorinated pyridinium cationic compounds of formula (I) and a medium, wherein the fluorinated pyridinium cationic compound of formula (I) is present at a concentration range of from about 0.001% to about 50% by weight, preferably a range of from about 0.01% to about 30% by weight, and more preferably a range of from about 0.05% to about 20% by weight.

The present invention further comprises a method of foaming a well fluid to be introduced into a well bore penetrating a hydrocarbon-containing subterranean zone comprising the steps of 1) providing a compound of formula (I) of the present invention, and 2) contacting the compound with compressed air or an inert gas to generate a foamed fluid.

The present invention further comprises a method of lowering the surface tension within a subterranean formation containing hydrocarbons comprising adding a compound of formula (I) as described above to a medium which is a carrier contacted with the subterranean formation. One method of contacting is injection of the carrier or medium into the subterranean formation, for example by using a downhole, well, or well bore. The compound of formula (I) is added to a carrier or medium such as a fluid or gas which will be in contact with the subterranean formation during operations to remove oil or gas from the formation. Examples include drill fluids, well fluids, stimulation fluids, liquid treatment streams, gas treatment streams, fractionating fluids, clay stabilizers, or other liquids or gases employed when extracting the hydrocarbons from the formation. The compounds of the present invention can be used in one or more of a pretreatment stage of injection of a pre-flush of various liquids, or in matrix or stimulation activities; in the main stage in various carrier fluids, or in a soaking of the formation for a specific time period; or in a post treatment stage for displacement operation to achieve better placement of the fluids containing the surfactant composition. The compound of the present invention is used in the form of a liquid, emulsion, dispersion, or foaming agent.

Foaming is a desirable property of the surfactants of the present invention which are used as additives to drill fluids, well fluids, and other fluids in oil and/or gas field applications for enhanced production and recovery. The aqueous or solvent based drilling fluids, well fluids, liquid or gas treatment streams, or other carrier compositions which contain the compound of the present invention foam during drilling or well treatment processes, and therefore provide advantages for enhanced production and recovery. Examples of such advantages from the surfactant and foaming properties include aiding in the removal of fines from the well around the drill-bit and wellbore treatment area, and adjusting the permeability and wettability properties where the fluids contact around the drill-bit and wellbore treatment area. The addition of the surfactant of the present invention boosts the foaming properties of the oil/gas well drilling fluids and treatment fluids. If these fines are not efficiently removed, they can result in damage to the drill-bit head, costing time and money to replace or repair. In addition the surfactant of the present invention is useful to reduce the viscosity of the hydrocarbon to permit easier extraction.

Another advantage of contacting a subterranean formation containing hydrocarbons with the fluorinated pyridinium cationic surfactant of the present invention as defined above, is providing a method for stimulating production of hydrocarbons during operations to extract hydrocarbons from a subterranean formation. The fluorosurfactant compounds of the present invention are useful as stimulation fluid additives for stimulation activities, such as hydraulic fracturing and acidizing. In these situations the stable foams of the present invention improve the wetting of the stimulation fluid on the formation surface (rock) to allow for deeper penetration and better stimulation of the well bore region. The low surface tension of these additives permit the stimulation fluids to be more efficiently and easily recovered from downhole. As a result, the well will be able to more effectively produce gas and oil.

The surfactant compounds of the present invention is further useful as an aid to prevent and remedy water blocks or condensate blocks in

wells and well bore areas. It is known that water can accumulate near the well bore of an oil or gas well and decrease productivity by decreasing the relative permeability of the oil or gas, which is called water block. In addition liquid hydrocarbons can also accumulate and cause a decrease in productivity in gas wells near or far from the well bore region known as condensate block. The compounds of the present invention can be used to help in removal of at least a portion of such accumulations of liquids in a water block or condensate block, or for reducing or preventing the formation of the accumulation of liquids in such blocks. The fluorinated pyridinium cationic surfactant of the present invention is useful as a surfactant additive in drill fluids, well fluids and treatment fluids for subterranean formation to alter the wettability and permeability by its surface active properties. Such surfactants, for example, are used within the porous rock medium of subterranean formation and can result in pressure changes or as foams can block the gas drain paths and result in the oil/gas recovery increases.

The compound of the present invention provides an advantage in that desirable surface effects are obtained using a surfactant containing a fully fluorinated perfluoroalkyl chain interrupted by oxygen. Thus the compositions of the present invention are advantageous over surfactants containing longer chain perfluoroalkyls or mixtures of homologues of perfluoroalkyls, each not interrupted by oxygen, while providing comparable or superior performance.

#### Materials and Test Methods

The following materials and test methods were used in the Examples herein.

#### Compound 1

Tetrafluoro ethylene (180 g) was introduced to an autoclave charged with  $C_3F_7OCF_2CF_2I$  (600 g), and the reactor was heated at 230 °C for 2 h. The same reaction was repeated twice. The products were combined and isolated by vacuum distillation to provide  $C_3F_7OCF_2CF_2CF_2CF_2CF_2CF_2I$  (234 g, 18%) b.p. 89~94 °C at 60 mmHg

( $79.98 \times 10^2$  Pascals) based on the recovery of starting material. The product was characterized by NMR below:

$^{19}\text{F}$  NMR (300 MHz,  $\text{CO}(\text{CD}_3)_2$ ): -65.33~-65.45 (2F, m), -82.72 (3F, t,  $J=7.2$  Hz), -84.08~84.21 (2F, m), -85.37~85.47 (2F, m), -114.60~114.75 (2F, m),  
 5 -121.96~122.18 (2F, m), -123.19 (2F, s), -126.43~-126.55 (2F, m), -131.09 (2F, s); and having mass of : MS: 613(  $\text{M}^+ + 1$ )

Ethylene (41.0 g, 1.46 mol) was introduced to an autoclave charged with  $\text{C}_3\text{F}_7\text{OCF}_2\text{CF}_2\text{CF}_2\text{CF}_2\text{CF}_2\text{I}$  (500 g, 0.82 mol). The reactor was then heated at 220 °C for 12 hours. Product

10  $\text{C}_3\text{F}_7\text{OCF}_2\text{CF}_2\text{CF}_2\text{CF}_2\text{CF}_2\text{CH}_2\text{CH}_2\text{I}$  was purified to greater than 99% purity via vacuum distillation (311.53g, b.p. 95 ~ 97 °C at 13 torr, 60% yield). The product was characterized by NMR below:

$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$  3.24 (2H, t-t,  $J_1 = 8.3$  Hz,  $J_2 = 2.0$  Hz), 2.78 ~ 2.63 (2H, m)

15  $^{19}\text{F}$  NMR ( $\text{CDCl}_3$ , 376 MHz)  $\delta$  -82.51 (3F, t,  $J = 7.2$  Hz), -83.92 ~ -84.07 (2F, m), -85.19 ~ -85.34 (2F, m), -115.75 ~ -115.97 (2F, m), -122.56 ~ -122.82 (2F, m), -123.06 ~ -123.30 (2F, m), -124.16 ~ -124.36 (2F, m), -126.29 ~ 126.46 (2F, m), -130.93 ~ -130.96 (2F, m); and having mass of: MS (PCI): 640 (  $\text{M}^+$ )

#### 20 Test Method 1—Surface Tension Measurement

A stock solution was prepared for the highest concentration of fluorosurfactant to be analyzed. The concentration of the solutions was by percent active ingredient, weight percent, or fluorine content. This stock solution was prepared in deionized water, 2% KCl water, or 15% HCl  
 25 water depending on the desired oilfield application for which the surface tension was being measured. The stock solution was stirred overnight (for approximately 12 hours) to ensure complete mixing. Additional concentrations of the fluorosurfactant for analysis were made by diluting the stock solution according to the equation  $M_i V_i = M_f V_f$ , where  $M_i$  is the  
 30 concentration of the stock solution,  $M_f$  is the concentration of the final solution,  $V_f$  is the final volume of the sample, and  $V_i$  is the volume of the stock solution that is needed in order to formulate the final sample. The

concentration dilution samples were shaken thoroughly and then left to sit undisturbed for 30 minutes. These samples were then mixed and poured into a small container. Solutions of 2% KCl and 15% HCl were typically used in the surface tension measurements for oilfield applications because they mimic the stimulation fluid types that are pumped down hole into wells. The 2% KCl solution was similar to the salinity of the fracture fluids that are used to hydraulically fracture a well. The 15% HCl solution emulated the acidizing stimulation treatment fluid that is used to help dissolve the formation rock in wells. The surface tension was measured using a Kruess Tensiometer, K11 Version 2.501 in accordance with instructions with the equipment. The Wilhelmy Plate method was used. A vertical plate of known perimeter was attached to a balance, and the force due to wetting was measured. 10 replicates were tested of each dilution, and the following machine settings were used:

Method: Plate Method SFT  
Interval: 1.0s  
Wetted length: 40.2mm  
Reading limit: 10  
Min Standard Deviation: 2 dynes/cm  
Gr. Acc.: 9.80665 m/s<sup>2</sup>  
Lower surface tension indicated superior performance.

#### Test Method 2-Foaming

The test procedure used to evaluate the foaming of fluorosurfactants for oilfield applications was a nitrogen bubble foaming test. First, stock solutions of the testing base solutions were made. These solutions were deionized water, 2% KCl, and 15% HCl. Samples of 20 mL of the fluorosurfactant at 0.1 % active ingredient in the desired base testing solution were prepared and stirred overnight to ensure complete mixing. The sample solution was then added to a 100 mL graduated cylinder (glass). Nitrogen was then bubbled through the solution to produce foam at a rate that filled the cylinder in 20-30 seconds. A fritted glass tube was used to bubble the nitrogen through the solution. When

the foam reached the top of the cylinder, the nitrogen was turned off and a timer was started. The heights of the foam and liquid in mL were measured after 30 seconds, 5 minutes, 10 minutes, and 15 minutes. A difference of up to 10 mL in foam height is within the variation of this method. Observations of the quality and persistency of the foam were also recorded. At least three repetitions were conducted for each sample test.

This nitrogen bubbling foam test was used as an indicator of the amount of foam that a sample produced and the persistency of that foam. Higher foam heights which lasted for a longer time indicated superior performance.

### EXAMPLES

#### Example 1

A 100 mL, three-neck roundbottom flask was charged with  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{I}$  (50.0 g, 0.0781 mol) and pyridine (39.1 g, 0.495 mol) under nitrogen. The reaction was allowed to reflux at 80 °C for 20 hours. The reaction mixture was cooled to room temperature before isolating the pale yellow solid product (52.9 g, 94%) in a fritted funnel. The product was washed with ethyl acetate (3 x 100 mL), and dried under vacuum overnight. The product was characterized as  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{N}^+(\text{C}_5\text{H}_5)^+\text{I}^-$ ; m.p. : 168 – 175 °C;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$  9.58 (2H, d, J= 5.9 Hz), 8.55 (1H, t, J= 7.8 Hz), 8.14 (2H, t, J= 7.1 Hz), 5.53 (2H, t, J= 6.0 Hz), 3.16 (2H, t-t, J1= 18.6 Hz, J2= 5.4 Hz)  $^{19}\text{F}$  NMR ( $\text{CDCl}_3$ , 376 MHz)  $\delta$  -81.70 (3F, t, J = 7.3 Hz), -83.30 ~ -83.47 (2F, m), -84.55 ~ -84.70 (2F, m), -112.78 ~ -113.03 (2F, m), -121.95 ~ -122.24 (2F, m), -122.58 ~ -122.84 (2F, m), -123.29 ~ -123.55 (2F, m), -125.70 ~ -125.92 (2F, m), -130.18 ~ -130.32 (2F, m)

A 100 mL, three-neck roundbottom flask equipped with a distillation column was charged with  $\text{C}_3\text{F}_7\text{O}(\text{CF}_2\text{CF}_2)_3\text{CH}_2\text{CH}_2\text{N}^+(\text{C}_5\text{H}_5)^+\text{I}^-$  (20.0 g, 0.0278 mol) and methanol (11.6 g, 0.363 mol) under nitrogen and heated to 60 °C. A solution of p-toluenesulfonic acid (6.18 g, 0.0325 mol) in

methanol (5.9 g, 0.184 mol) was added drop wise into the reaction flask. The reaction was heated to 60 °C for 80 hours (when CH<sub>3</sub>I could no longer be detected by GC in the distillate), while additional methanol was added periodically to replenish the distilled solvent. Methanol was then  
5 evaporated off to yield the product C<sub>3</sub>F<sub>7</sub>O(CF<sub>2</sub>CF<sub>2</sub>)<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>N<sup>+</sup>(C<sub>5</sub>H<sub>5</sub>) p-CH<sub>3</sub>C<sub>6</sub>H<sub>4</sub>SO<sub>3</sub><sup>-</sup> as a yellow solid (21.58 g, 100%). The product was then dissolved in methanol to obtain a 50% solution, and neutralized to a pH of 5.5 ± 0.5 with 3.5% NaOH aqueous solution. The product was characterized as:

10 <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 9.30 (2H, d, J=5.8 Hz), 8.34 (1H, t, J=8.0 Hz), 7.95 (2H, t, J= 7.1 Hz), 7.67 (2H, d, J=8.1 Hz), 7.11 (2H, d, J = 8.1 Hz), 5.87(1H, NH, s), 5.27 (2H, t, J=6.2 Hz), 2.94 (2H, t-t, J1 = 18.7 Hz, J2 = 6.1 Hz)  
<sup>19</sup>F NMR (CDCl<sub>3</sub>, 376 MHz) δ -81.84 (3F, t, J = 7.3 Hz), -83.44 ~ -  
15 83.62 (2F, m), -84.66 ~ -84.83 (2F, m), -113.40 ~ -113.64 (2F, m), -122.17 ~ -122.46 (2F, m), -122.77 ~ -123.00 (2F, m), -123.64 ~ -123.85 (2F, m), -125.88 ~ -126.08 (2F, m), -130.35 ~ -130.40 (2F, m).

The product was tested for surface tension and foaming using Test  
20 Methods 1 and 2. Results are in Tables 1 to 6.

#### Comparative Example A

The process of Example 1 was employed with the formula C<sub>8</sub>F<sub>17</sub>CH<sub>2</sub>CH<sub>2</sub>I. The resulting product C<sub>8</sub>F<sub>17</sub>CH<sub>2</sub>CH<sub>2</sub>N<sup>+</sup>(C<sub>5</sub>H<sub>5</sub>) p-CH<sub>3</sub>C<sub>6</sub>H<sub>4</sub>SO<sub>3</sub><sup>-</sup> was tested for surface tension and foaming using test  
25 Methods I and 2. The results are in Tables 1 to 6.

#### Comparative Example B

The process of Example 1 was employed using the formula C<sub>6</sub>F<sub>17</sub>CH<sub>2</sub>CH<sub>2</sub>I as a starting material. The resulting product C<sub>6</sub>F<sub>17</sub>CH<sub>2</sub>CH<sub>2</sub>N<sup>+</sup>(C<sub>5</sub>H<sub>5</sub>) p-CH<sub>3</sub>C<sub>6</sub>H<sub>4</sub>SO<sub>3</sub><sup>-</sup> was tested for surface tension and  
30 foaming using Test Methods 1 and 2. Results are in Tables 1 to 6.

Table 1 - Surface Tension in Deionized Water (dynes/cm)

Example*	0%	0.001%	0.01%	0.1%	0.5%
1	72.5	49.7	20.6	15.7	15.5
Comparative A	72.8	62.5	31.0	17.0	16.9
Comparative B	72.7	72.2	59.3	26.5	16.9

\*Example was added to deionized water by weight based on solids of the additive in methanol; standard deviation was less than 1 dynes/cm; temperature 23°C.

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Table 2 – Surface Tension in 2% KCl Aqueous Solution (dynes/cm)

Example*	0%	0.001%	0.01%	0.1%	0.5%
1	74.0	22.7	18.8	16.0	15.6
Comparative A	74.3	41.1	20.3	18.1	17.0
Comparative B	74.3	65.9	51.4	27.5	18.8

\*Example was added to 2% KCl aqueous solution by weight based on solids of the additive in methanol

\*Standard Deviation <1 dynes/cm

10 \*Temperature 23°C

Table 3 - Surface Tension in 15% HCl Aqueous Solution (dynes/cm)

Example*	0%	0.001%	0.01%	0.1%	0.5%
1	71.7	21.8	17.8	17.0	16.4
Comparative A	72.2	39.4	19.9	19.3	19.0
Comparative B	72.8	63.7	47.8	26.8	22.8

\*Example was added to 15% HCl aqueous solution by weight based on solids of the additive in methanol; standard deviation <1 dynes/cm;

15 temperature 23°C

The normal surface tension of deionized water, 2% KCl aqueous solution and 15% HCl aqueous solution is about 72 dyne/cm (shown in Tables 1 to 3 as 0.000%). When the fluorosurfactant of the present

invention was added at a specified rate, the surface tension of each aqueous solution was reduced significantly. Better performance was obtained at higher levels. According to the results from the test, superior surface tension reduction was seen from the Example 1 of the present invention versus the Comparative Examples A and B.

Table 4 - Foaming in Deionized Water

Example*	Foam Volume (mL)				
	Initial	t=30 sec	t=5 min	t=10 min	t=15 min
1	97	96	81	71	66
Comparative A	108	105	98	92	86
Comparative B	98	13	7	2	0

\*Example was added to deionized water by weight based on solids of the additive in methanol to make 100 mL 0.1% solution

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Table 5 - Foaming in 2% KCl Aqueous Solution

Example*	Foam Volume (mL)				
	Initial	t=30 sec	t=5 min	t=10 min	T=15 min
1	101	96	81	66	61
Comparative A	100	97	96	91	86
Comparative B	104	44	4	3	3

\*Example was added to 2% KCl aqueous solution by weight based on solids of the additive in methanol to make 100 mL 0.1% solution

Table 6 - Foaming in 15% HCl Aqueous Solution

Example*	Foam Volume (mL)				
	Initial	t=30 sec	t=5 min	t=10 min	T=15 min
1	93	81	76	71	71
Comparative A	99	97	91	86	81
Comparative B	118	103	48	42	19

\*Example was added to 15% HCl aqueous solution by weight based on solids of the additive in methanol to make 100 mL 0.1% solution

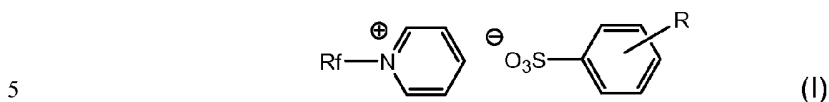
5            Example 1 of the present invention showed excellent initial performance and generally comparable performance over time versus the Comparative Example A. Example 1 showed superior performance to Comparative Example B which did not sustain foam over time.

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CLAIMSWhat is claimed is:

1. A compound of formula (I)



wherein

R<sub>f</sub> is R<sup>1</sup>(CH<sub>2</sub>CH<sub>2</sub>)<sub>n</sub>-,

- R<sup>1</sup> is a C<sub>7</sub> to C<sub>20</sub> perfluoroalkyl group interrupted by at least one  
 10 catenary oxygen atom, each oxygen bonded to two carbon atoms,  
 n is an integer of 1 to 3, and

R is H, C<sub>1</sub> to C<sub>5</sub> linear or branched alkyl, or C<sub>1</sub> to C<sub>5</sub> linear or  
 branched alkoxy.

2. The compound of claim 1 having a surface tension of about  
 15 25 mN/m or less at a concentration of 0.1% by weight in aqueous solution.

3. The compound of claim 1 further comprising a liquid or a  
 solvent selected from the group consisting of water, saline solution, KCl  
 solution, HCl solution, hydrocarbon, halocarbon, drill fluid, well fluid, liquid  
 treatment stream for subterranean formations and gas treatment stream  
 20 for subterranean formations.

4. The composition of claim 3 wherein the compound of formula  
 (I) is present at a concentration range of from 0.001% to 50% by weight.

5. The compound of claim 1 in the form of a foam.

6. A method of modifying a surface effect of an aqueous  
 25 medium or solvent medium comprising contacting the medium with a  
 compound of formula (I) as defined in claim 1.

7. The method of claim 6 wherein the medium is selected from the group consisting of water, saline solution, KCl solution, HCl solution, drill fluids, well fluids, liquid treatment or gas treatment stream for  
5 subterranean formation and well bore areas, hydrocarbon, halocarbon system, coating composition, latex, polymer, floor finish, floor polish, fire fighting agent, ink, emulsifying agent, foaming agent, release agent, repellency agent, flow modifier, film evaporation inhibitor, wetting agent, penetrating agent, cleaner, grinding agent, electroplating agent, corrosion  
10 inhibitor, etchant solution, soldering agent, dispersion aid, microbial agent, pulping aid, rinsing aid, polishing agent, personal care composition, drying agent, antistatic agent, and bonding agent.

8. The method of claim 6 wherein the surface effect is selected from the group consisting of lowering the surface tension, wetting,  
15 penetration, spreading, leveling, flowing, emulsifying, dispersing, repelling, releasing, lubricating, etching, bonding, and stabilizing.

9. The method of claim 6 wherein the compound of formula (I) is added to a medium to be contacted with a hydrocarbon-bearing subterranean formation and wherein the medium is selected from the  
20 group consisting of water, saline solution, KCl solution, HCl solution, hydrocarbons, halocarbons, drill fluids, well fluids, stimulating fluids, and liquid treatment or gas treatment stream for subterranean formation and well bore areas.

10. The method of claim 9 wherein the compound of formula (I)  
25 is present in the medium at a concentration of from about 0.001% to about 50% by weight.