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Design and synthesis of novel perfluoroalkyl-containing zinc pyrithione biocide

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Abstract—Novel perfluoroalkyl-containing zinc pyrithione biocide **2** was designed and synthesized in six steps. Reaction of 4-methylpyridine with $C_8F_{17}(CH_2)_3I$ in the presence of LDA followed by further oxidization of the resultant pyridine derivative **6** gave the pyridine *N*-oxide **9**. Treatment of **9** with phosphorous oxychloride afforded the desirable chloride **12**. Oxidization of compound **12** with H_2O_2 gave *N*-oxide **14**, which was treated with NaSH to give the sulfide **3**. Finally, treatment of compound **3** with NaOH/$ZnSO_4$ smoothly delivered perfluoroalkyl-containing zinc pyrithione biocide **2** in good yield.
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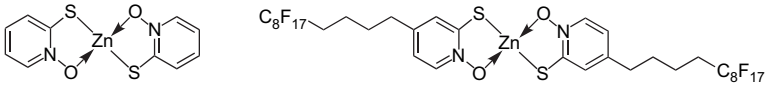
1. Introduction

Nowadays, Zinc pyrithione (also known as Zinc Omadine®, ZPT or zinc bis(2-pyridylthio)-*N*-oxide, **1**, Fig. 1) is used more and more extensively in routine life. Apart from preventing microbial degradation and deterioration of manufacturing starting materials such as plastics, polymers, and latexes, ZPT is used to prevent the growth of bacteria, fungi, mildew, and algae, which can cause various types of deterioration such as discoloration, staining, odors, etc. In addition, ZPT is the key active ingredient in various shampoos used to control dandruff and seborrheic dermatitis.[1–3] Furthermore, it is also registered for incorporation into antifoulant boat paints to control the growth of slime, algae, and marine fouling organisms below the water line on recreational and commercial boat hulls.[4,5]

Actually, biofouling is a serious problem for the shipping industry. To prevent boat hulls from fouling, lead and later copper sheathings were developed to address it in ancient years. In the 1970s, tributyltin (TBT) compounds, which were effective against both soft (e.g., algae) and hard fouling organisms, were introduced. However, although tin compounds are effective, the toxicity of released TBT is persistent in the environment and has adversely affected population of non-target organisms. Thus, TBT suffered from the international ban in antifouling paints. Fortunately, ZPT and its combination with cuprous oxide has been identified, a virtual substitute for TBT, to be effective against fouling organisms. Now, ZPT has been introduced into the market as an effective replacement for traditional TBT-based antifouling paints (for more information, see: http://www.archchemicals.com/Fed/Corporate/News).

In spite of many advantages of ZPT, it also suffers some drawbacks. For example, ZPT would stimulate eyes when it directly comes in contact with eyes when used in shampoos; it would slowly degrade when exposed to ultraviolet radiation. Thus, there keeps a strong demand for better substitution for ZPT, especially ZPT analogues.



Zinc pyrithione (ZPT) **1** Target molecule **2**

Figure 1. ZPT **1** and target compound **2**.

Keywords: Zinc pyrithione; Biocide; Perfluoroalkyl-containing compounds.
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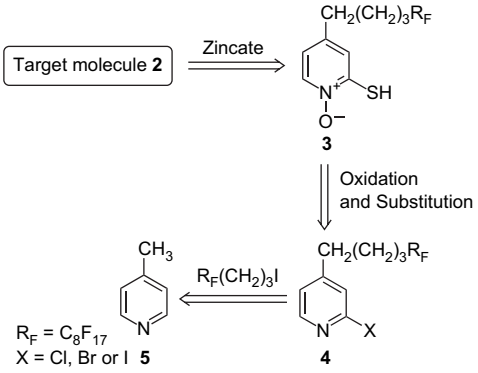
It is well known that introduction of fluorine atom(s) or fluorine-containing group into an organic compound can bring about remarkable changes in the physical, chemical, and biological properties.[6] The perfluoroalkylated tails are intended to increase the hydrophobic character[7] in order to render more waterproof or water insoluble compounds. Moreover, in some cases,[8] the introduction of perfluoroalkyl group into some compounds can not only efficiently enhance the antimicrobial activity, but also extend its application fields. Herein, we wish to report the synthesis of the novel perfluoroalkyl-containing zinc pyrithione biocides **2** (Fig. 1). Rational of target compound **2** was mainly based on the following points. Firstly, $R_F(CH_2)_4$ group was located in the C-4 position of pyrithione skeleton, which may reduce the direct influence of the blocking effect on the chelation of zinc with sulfide and oxygen atoms. In addition, R_F was connected to pyrithione through the linkage $-(CH_2)_4-$, which may eliminate the effect of strong electron-withdrawing R_F group on pyrithione ring and make oxygen atom and sulfur atom to chelate well with zinc.

2. Results and discussion

On the basis of retrosynthetic analysis (Scheme 1), 4-substituted pyrithione **3** would be reached by oxidization of pyridine derivative **4** followed by substitution of SH for halogen atom. Thus, how to prepare the intermediate **4** from 4-methyl-pyridine **5** is the key for the whole synthesis.

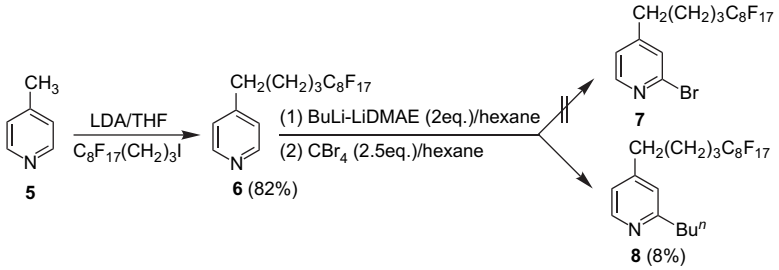


Scheme 1.

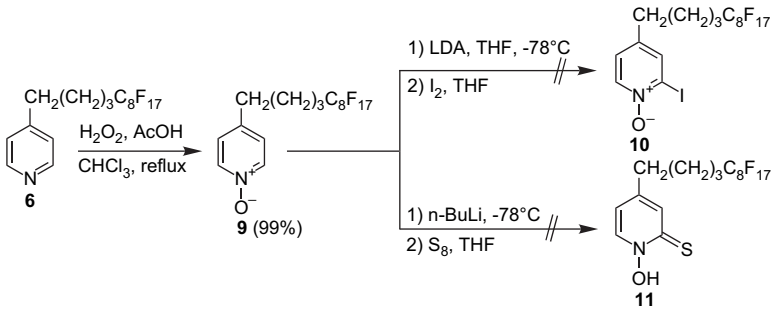
Accordingly, treatment of 4-methyl-pyridine **5** with LDA in THF followed by addition of $C_8F_{17}(CH_2)_3I$ to the resultant mixture smoothly gave the pyridine derivative **6** in 82% yield (Scheme 2).[7,9] Then, our eyesight was focused on the methodology reported by Kaminski et al.,[10] that 2,4-disubstituted pyridine derivatives were easily accessed by treatment of 4-pyridine derivatives with BuLi–$Me_2N(CH_2)_2OLi$(BuLi–LiDMAE) followed by electrophiles. However, lithiation of compound **6** with BuLi–LiDMAE/hexane followed by treatment with electrophile CBr_4 failed to afford the desired bromide **7**, only the byproduct **8** was obtained in 8% yield. Considering the low solubility of compound **6** in hexane, trifluoromethylbenzene/hexane as cosolvents and (or), addition of large excess of BuLi–LiDMAE was attempted, however, reactions still did not work. In our opinion, reaction failures were attributed to the possibility that *n*-BuLi–LiDMAE in hexane or trifluoromethylbenzene was not powerful enough to deprotonate compound **6** to form its carbanion. Kessar et al.[11] described that treatment of 4-substituted pyridine derivatives with $BF_3\cdot Et_2O$ and subsequent lithiation with an excess of lithium tetramethylpiperidide (LTMP) was also an efficient strategy for selective lithiation at C-2 position of pyridine derivatives. However, Kessar′s method still did not afford our desired product **7**.

It is well known that substitution of hydrogen in pyridine 1-oxide and its derivatives has been achieved in a number of cases by base-induced proton-abstraction followed by in situ treatment with a suitable electrophile.[12,13] Furthermore, Mongin et al.[14] successfully synthesized a series of 2-substituted pyridine *N*-oxides by the metalation of the pyridine *N*-oxide. Comparing to the corresponding pyridine derivatives, pyridine *N*-oxides indeed were more prone to metalation in C-2 position because of enhanced acidity of 2-H. Accordingly, oxidation of compound **6** with hydrogen peroxide (30% aq solution) smoothly gave the pyridine *N*-oxide **9** in almost quantitative yield (Scheme 3). However, treatment of compound **9** with LDA or LTMP at −78 °C followed by quenching the reaction with iodine failed to afford 2-iodine-4-fluoroalkyl-pyridine *N*-oxide **10**. In addition, Abramovitch et al. developed a general method for synthesis of pyridine cyclic thiohydroxamic acids, involving the addition of elemental sulfur to lithiopyridine 1-oxides.[15] Unfortunately, treatment of compound **9** with *n*-BuLi at low temperature followed by addition of elemental sulfur still did not provide our desired compound **11** (Scheme 3).

In view of the above failures, we thought that it was due to the deficiency of π-electron in the pyridine heterocycles, which resulted from the inductive effect of the perfluoroalkyl segments though the R_F group was segregated to heterocycle by four methylene units. Thus, reductive chlorination

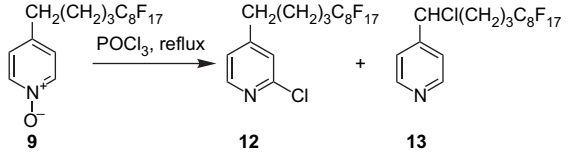


Scheme 2.



Scheme 3.

strategy developed by Queguiner et al.[16] was attempted to synthesize key intermediate **4**. To our delight, treatment of compound **9** with $POCl_3$ under reflux condition provided our desired halogenated pyridine **12** along with the byproduct **13** (Scheme 4). Interestingly, we found that the yield of byproduct **13** could be sharply decreased by lowering the amount of $POCl_3$, although the yield of compound **12** had no significant change.



$POCl_3$	reaction time	product (% yield)	
		12	**13**
10 eq.	4h	34	28
5 eq.	4h	35	7

Scheme 4.

Similar to the preparation of compound **9** from pyridine derivative **6**, pyridine *N*-oxide **14** was afforded by oxidation of chloride **12** in 79% yield (Scheme 5). Then, introduction of the requisite mercapto group was achieved via reaction of compound **14** with NaSH and sulfide **3** was furnished in 81% yield.[17,18] Finally, treatment of compound **3** with an aq NaOH followed by aq $ZnSO_4$ successfully gave our target molecule **2** in 84% yield.[19]

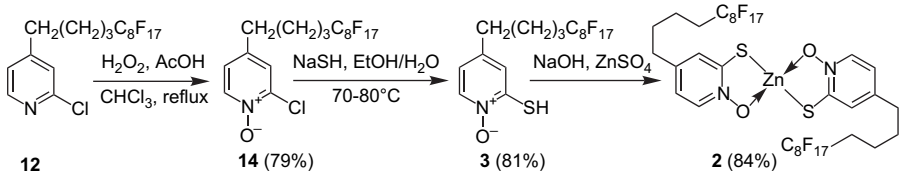
In summary, novel perfluoroalkyl-containing zinc pyrithione biocide was designed and synthesized. The key intermediate **12** was successfully afforded by reductive chlorination of compound **9** with $POCl_3$ although several lithiation strategies failed to give the desired compounds. Starting from compound **12**, target compound **2** was smoothly synthesized in a straightforward fashion. Studies on antibacterial activity and other usage of perfluoroalkyl-containing zinc pyrithione **2** are currently in progress.

3. Experimental

3.1. General methods

Melting points were determined on a Pai-ke melting point apparatus and were uncorrected. ^1H and ^{19}F NMR spectra were recorded on a Bruker AM 400 spectrometer, with TMS as an internal standard for ^1H NMR spectroscopy and $CFCl_3$ as an external standard for ^{19}F NMR spectroscopy. All chemical shifts (δ) were recorded in parts per million and coupling constants (J) were given in hertz. MS (EI, 70 eV) spectra were recorded with a Finnigan-MAT-8430 spectrometer. IR spectra were recorded on a Thermo Electron Corporation Nicolet 380 FT-IR spectrophotometer. THF and hexane were distilled from benzophenone/Na. 4-Methyl-pyridine, diisopropylamine, and 2-(dimethylamino)ethanol were distilled under nitrogen and stored over 4 Å molecular sieves. $C_8F_{17}(CH_2)_3I$ was synthesized according to literature.[20,21]

3.1.1. 4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-Heptadecafluorododecyl)pyridine (6). *n*-Butyllithium (14.5 mL, 1.6 M in hexane, 23.2 mmol, 1.2 equiv) was added, via a syringe, to a solution of diisopropylamine (3.26 mL, 23.2 mmol, 1.2 equiv) in tetrahydrofuran (10 mL) at −78 °C. The solution was stirred at −78 °C for 0.5 h and then a solution of 4-methyl-pyridine (2.15 g, 23.09 mmol, 1.2 equiv) in THF (5 mL) was added dropwise. The resultant yellow mixture was stirred at −78 °C for 3 h. Then a solution of 1,1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-heptadecafluoro-11-iodoundecane (11.30 g, 19.22 mmol, 1.0 equiv) in THF (15 mL) was added dropwise. The reaction mixture was slowly warmed to room temperature and stirred overnight. The reaction was quenched with methanol (5 mL) and the resultant yellow-brown solution was poured into cold water. The solution was extracted with diethyl ether (3×50 mL) and combined organic phases were dried over anhydrous Na_2SO_4. After filtration and removal of the organic solvent, the residue was purified by silica gel (petroleum ether/ethyl acetate, 5:1) to give compound **6** as white crystals (8.68 g, 82%



Scheme 5.

yield). Mp: 38.5–40.5 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.51 (d, J=8.0 Hz, 2H), 7.12 (d, J=8.0 Hz, 2H), 2.67 (t, J=8.0 Hz, 2H), 2.15–2.04 (m, 2H), 1.77–1.64 (m, 4H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.73 (t, J=11.3 Hz, 3F), −114.25 to −114.34 (m, 2F), −121.70 to −121.91 (m, 6F), −122.68 (s, 2F), −123.48 (s, 2F), −126.10 (s, 2F); IR (thin film) 658, 704, 955, 1073, 1116, 1147, 1171, 1216, 1251, 1332, 1372, 1469, 1603, 2919, 2949, 3440 cm^{-1}; MS (EI): m/z (%)=92 (29.5), 93 (100), 106 (12.4), 534 (13.3), 553 (M^+, 25.6), 554 (5.87, M^++1); Anal. Calcd for $C_{17}H_{12}F_{17}N$: C, 36.91; H, 2.19; N, 2.53. Found: C, 37.11; H, 2.28; N, 2.45.

3.1.2. 2-Butyl-4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-heptadecafluorododecyl)pyridine (8). After a solution of 2-(dimethylamino)ethanol (0.4 mL, 3.9 mmol, 2.0 equiv) in hexane (1.5 mL) was cooled to 0 °C, n-butyllithium (4.9 mL, 1.6 M in hexane, 7.8 mmol, 4.0 equiv) was added dropwise. Then, the mixture was stirred at 0 °C for 0.5 h. After that, a solution of compound **6** (1.08 g, 1.95 mmol, 1.0 equiv) in hexane (2.0 mL) was added dropwise. After the reaction was further stirred for 1 h at 0 °C, the organic solution was cooled to −78 °C and treated with a solution of CBr_4 (1.62 g, 4.9 mmol, 2.5 equiv) in THF (5 mL). After 3 h at −78 °C, the mixture was warmed to room temperature and reaction was quenched with H_2O (5 mL) at 0 °C. The organic layer was then extracted with diethyl ether (3×15 mL) and the combined organic phases were dried over anhydrous $MgSO_4$. After filtration and removal of the organic solvent, the residue was purified by silica gel (petroleum ether/ethyl acetate, 5:1) to give compound **8** as a yellow oil (0.10 g, 8% yield). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.42 (d, J=5.0 Hz, 1H), 6.96 (s, 1H), 6.91 (d, J=5.0 Hz, 1H), 2.79–2.75 (t, J=8.0 Hz, 2H), 2.64–2.60 (t, J=8.0 Hz, 2H), 2.12–2.07 (m, 2H), 1.75–1.66 (m, 6H), 1.42–1.36 (m, 2H), 0.94 (t, J=7.0 Hz, 3H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.99 (s, 3F), −114.32 to −114.41 (m, 2F), −121.76 to −121.99 (m, 6F), −122.79 (s, 2F), −123.58 (s, 2F), −126.21 (s, 2F); IR (thin film) 559, 656, 721, 828, 1028, 1115, 1151, 1206, 1242, 1329, 1413, 1468, 1560, 1605, 2957 cm^{-1}; MS (EI): m/z (%)=106 (23.9), 107 (32.0), 119 (124.7), 567 (100), 568 (21.2), 5580 (28.3), 94 (M^+-CH_3, 12.5), 610 (M^++1, 23.4); Anal. Calcd for $C_{21}H_{20}F_{17}N$: C, 41.39; H, 3.31; N, 2.30. Found: C, 41.50; H, 3.35; N, 2.32.

3.1.3. 4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-Heptadecafluorododecyl)-1-hydroxypyridinium (9). Hydrogen peroxide (30% aq solution, 30 mL) was added dropwise to a solution of compound **6** (5.54 g, 10.01 mmol) in chloroform (20 mL) and then acetic acid (5 mL) was added at 0 °C. The solution was stirred at room temperature for 3 h. After that, the mixture was heated to reflux for 18 h. Then, the reaction mixture was poured into water and extracted with CH_2Cl_2 (3×30 mL). The combined organic phases were dried over anhydrous Na_2SO_4. After filtration and removal of the organic solvent, the residue was purified by silica gel (CH_2Cl_2/MeOH, 15:1) to give compound **9** as white crystals (5.66 g, 99% yield). Mp: 77.5–78.5 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.19 (d, J=8.0 Hz, 2H), 7.12 (d, J=8.0 Hz, 2H), 7.68 (t, J=8.0 Hz, 2H), 2.16–2.07 (m, 2H), 1.76–1.65 (m, 4H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.73 (t, J=11.3 Hz, 3F), −114.11 to −114.19 (m, 2F), −121.59 to −121.81 (m, 6F), −122.61 (s, 2F), −123.39 (s, 2F), −126.00 (t, J=11.3 Hz, 2F); IR (thin film) 566, 733, 781, 941, 1020, 1113, 1136, 1206, 1287, 1510, 1575, 1689, 1792, 2550, 2667, 2983, 3064, 3430 cm^{-1}; MS (EI): m/z (%)=91 (5.6), 93 (14.5), 108 (100), 109 (9.7), 121 (3.8), 569 (M^+, 24.4), 570 (M^++1, 5.8); Anal. Calcd for $C_{17}H_{12}F_{17}NO$: C, 35.87; H, 2.12; N, 2.46. Found: C, 35.46; H, 2.34; N, 2.32.

3.1.4. 2-Chloro-4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-heptadecafluorododecyl)pyridine (12) and 4-(1-chloro-5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-heptadecafluorododecyl)pyridine (13). Phosphorus oxychloride (30 mL) was added to compound **9** (1.75 g, 3.07 mmol) and the resultant solution was heated to reflux for 4 h. Then, the solvent was removed in vacuo and H_2O (20 mL) was added to the resultant red-brown residue. After the mixture was neutralized with aq K_2CO_3, the solution was extracted with methylene dichloride (3×20 mL). The combined organic phases were dried over anhydrous Na_2SO_4. After filtration and removal of the organic solvent, the residue was purified by silica gel to give compound **12** (0.61 g, 34% yield) and compound **13** (0.50 g, 28% yield) as white solids.

Compound **12**: Mp<16.5 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.29 (d, J=4.0 Hz, 1H), 7.17 (s, 1H), 7.05 (d, J=4.0 Hz, 1H), 2.66 (t, J=8.0 Hz, 2H), 2.05–2.06 (m, 2H), 1.76–1.67 (m, 4H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.76 (t, J=11.3 Hz, 3F), −114.25 to −114.34 (m, 2F), −121.69 to −121.91 (m, 6F), −122.70 (s, 2F), −123.49 (s, 2F), −126.09 (s, 2F); IR (thin film) 527, 559, 653, 706, 824, 890, 948, 997, 1029, 1082, 1148, 1217, 1254, 1328, 1381, 1393, 1467, 1548, 1593, 2872, 2950, 3052, 3440 cm^{-1}; MS (EI): m/z (%)=69 (6.7), 91 (14.4), 126 (15.2), 127 (100), 129 (37.0), 587 (M^+, 11.3), 588 (M^++1, 8.5); Anal. Calcd for $C_{17}H_{11}F_{17}NCl$: C, 34.74; H, 1.89; N, 2.38. Found: C, 34.92; H, 1.67; N, 2.25.

Compound **13**: Mp: 22.5–24.5 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.65 (s, 2H), 7.32 (s, 2H), 4.92–4.80 (m, 1H), 2.36–2.31 (m, 1H), 2.19–2.06 (m, 3H), 1.74–1.72 (m, 1H), 1.30–1.27 (m, 1H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.72 (s, 3F), −114.21 to −114.29 (m, 2F), −121.66 to −121.88 (m, 6F), −122.68 (s, 2F), −123.25 to −123.45 (m, 2F), −126.07 (s, 2F); IR (thin film) 573, 657, 704, 722, 814, 957, 1059, 1115, 1135, 1147, 1210, 1260, 1332, 1419, 1464, 1598, 2930, 2969, 3431 cm^{-1}; MS (EI): m/z (%)=91 (23.1), 92 (100), 118 (46.1), 127 (47.4), 126 (82.7), 379 (21.4), 552 (49.9), 587 (M^+, 28.6); Anal. Calcd for $C_{17}H_{11}F_{17}NCl$: C, 34.74; H, 1.89; N, 2.38. Found: C, 34.76; H, 1.74; N, 2.32.

3.1.5. 2-Chloro-4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-heptadecafluorododecyl)-1-hydroxypyridinium (14). To a solution of compound **12** (1.55 g, 2.64 mmol) in chloroform (10 mL), hydrogen peroxide (30% aq solution, 10 mL) and acetic acid (1.5 mL) were added dropwise at 0 °C. After dripping off, the solution was stirred at room temperature for 3 h. Then, the mixture was heated to reflux for 20 h. The reaction mixture was poured into water and then extracted with methylene dichloride (5×15 mL). The combined organic layers were dried over anhydrous Na_2SO_4. After filtration and removal of the organic solvent, the residue was purified by silica gel (methylene dichloride/methanol, 20:1) to give compound **14** as white crystals (1.26 g, 79% yield).

Mp: 58–60 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.32 (d, J=4.0 Hz, 1H), 7.34 (s, 1H), 7.05 (d, J=4.0 Hz, 1H), 2.67 (t, J=8.0 Hz, 2H), 2.19–2.10 (m, 2H), 1.75–1.68 (m, 4H); ^{19}F NMR ($CDCl_3$, 376 MHz): δ −80.72 (t, J=11.3 Hz, 3F), −114.20 to −114.33 (m, 2F), −121.67 to −121.88 (m, 6F), −122.67 (s, 2F), −123.44 (s, 2F), −126.05 (s, 2F); IR (thin film) 557, 652, 800, 837, 1025, 1115, 1150, 1205, 1250, 1373, 1331, 1419, 1465, 1605, 2852, 2921, 2950, 3064, 3097, 3432 cm^{-1}; MS (EI): *m/z* (%)=69 (5.5), 129 (4.5), 142 (100), 144 (35.4), 603 (M^+, 50.8), 604 (M^++1, 11.8), 605 (M^++2, 18.2); Anal. Calcd for $C_{17}H_{11}F_{17}NOCl$: C, 33.82; H, 1.84; N, 2.32. Found: C, 33.75; H, 1.85; N, 2.28.

3.1.6. 4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-Heptadecafluorododecyl)-1-hydroxy-2-mercaptopyridinium (3). A solution of compound **14** (0.88 g, 1.46 mmol) in H_2O (10 mL) and EtOH (5 mL) was heated to 70 °C. Then, a solution of NaSH (0.33 g, 5.83 mmol) in H_2O (5 mL) was added dropwise. After that, the reaction mixture was further heated to 85 °C and stirred for 1 h. Then, the decolorizing carbon (0.5 g) was added and the resultant mixture was filtered. The filtrate was cooled to 15–25 °C and the pH of solution was adjusted to 1.7 with hydrochloric acid (20%). The precipitated khaki compound **3** (0.71 g, 81% yield) was recovered immediately, recrystallized from hot ethanol and dried. Mp: 107–112 °C; ^{1}H NMR (MeOD, 400 MHz): δ 8.36–8.32 (m, 1H), 7.56 (s, 1H), 7.31–7.26 (m, 1H), 2.70 (t, J=8.0 Hz, 2H), 2.19–2.03 (m, 2H), 1.70–1.61 (m, 4H); ^{19}F NMR (MeOD, 376 MHz): δ −80.39 (s, 3F), −115.37 to −115.50 (m, 2F), −122.72 to −122.93 (m, 6F), −123.76 (s, 2F), −124.47 (s, 2F), −127.30 (s, 2F); IR (thin film) 531, 560, 658, 705, 807, 872, 1027, 1115, 1150, 1204, 1332, 1465, 1538, 1608, 2949, 3435 cm^{-1}; MS (EI): *m/z* (%)=65 (34.3), 80 (89.3), 109 (100), 125 (81.5), 585 (58.5), 601 (M^+, 32.0); HRMS Calcd for $C_{17}H_{13}NOF_{17}S$ (M^++1), 602.0431. Found: 602.0441.

3.1.7. Zinc bis(4-(5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,12-heptadecafluorododecyl)-2-pyridylthio)-*N*-oxide (2). A solution of compound **3** (0.40 g, 0.67 mmol) in EtOH (10 mL) was added to a solution of NaOH (0.03 g, 0.75 mmol) in H_2O (5 mL). After stirring for half an hour, a solution of $ZnSO_4\cdot 7H_2O$ (0.098 g, 0.34 mmol) in H_2O (10 mL) was added to the mixture dropwise. A white precipitate was formed immediately and was collected by filtration. Resultant solid compound was washed with water, alcohol, and ether and air-dried. The compound **2** (0.72 g, 84% yield) was finally obtained after solid compound was kept in vacuum for about 1 h. Mp>300 °C; IR (thin film) 422, 617, 639, 657, 705, 806, 874, 1028, 1115, 1149, 1204, 1332, 1370, 1468, 1534, 1615, 2854, 2922, 3429 cm^{-1}; HRMS Calcd for $C_{34}H_{22}N_2O_2F_{17}S_2Zn$ (M^+), 1263.9819; $C_{34}H_{23}N_2O_2F_{17}S_2Zn$ (M^++1), 1264.9920. Found: 1263.9866; 1264.9944.

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