Electroreductive Defluorination of Trifluoromethyl Ketones and Trifluoroacetic Acid Derivatives

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Difluoroenol silyl ethers **5** and **6**, difluoroketene silyl (*O,O*-, *O,S*-, and *O,N*-) acetals **9** and **21**, and 2,2-difluoro-2-trimethylsilylacetates **10** were prepared by electroreductive defluorination of trifluoromethyl ketones and trifluoroacetic acid derivatives in an MeCN−TBAB−chlorotrialkylsilane system using a carbon rod as an anode and a lead plate as a cathode. TBAF- or KF−CuI-promoted α-alkylation of **10** with electrophiles such as aldehydes, ketones, imine, acylhalides, and alkylhalides provided α-alkylated-α,α-difluoroacetates in good to excellent yields.

Introduction

Introduction of a difluoromethylene unit into organic molecules is an important subject in current organofluorine chemistry[1] since recent works have revealed a wide range of biologically interesting difluoromethylene compounds such as anticancer agent gemcitabine,[2] HIV-1 protease inhibitors,[3] and phosphotyrosine (pTyr) mimetics.[4] For this reason, a variety of methods for the preparation of functionalized difluoromethylene compounds have been developed.[5] Among them, CF_2 building blocks with an enol ether moiety[6] and difluoroketene silyl acetals[7] are promising candidates for the difluoro compounds, and their synthetic utilization has been demonstrated in fluorinated sugars and amino acids syntheses.[8]

Constructions of difluoromethylene units are usually achieved by the transformation of a ketonic carbonyl group or its equivalent using fluorinating agents such as DAST,[9] NBS−HF−amine complexes,[10] and the reaction of difluorocarbenes[11] and so on. However, the practical applicability of these approaches is often limited by the requirement to deploy a carbonyl group at the strategic position of suitably protected precursors, as well as by the hazardous and reactive nature of most fluorinating agents. An attractive alternative approach is to make use of readily accessible CF_2-containing building blocks. As an example, Reformatsky-type reactions of halodifluoroacetates[7,12] are widely used to synthesize the difluoroketene silyl acetals. However, less availability of halodifluoroacetates is one of the drawback in these methods, so more reliable methods are strongly required. The selective monodefluorination of easily available trifluoromethyl compounds as starting materials is promising for this purpose.

Selective defluorinations from a trifluoromethyl group such as base-catalyzed dehydrofluorination of a 2,2,2-trifluoroethyl group,[13] chemical[6b] and electrochemical[14] reductive defluorination of trifluoromethylaromatics, S_N2'-type substitution of trifluoromethyl olefins[15] and imines,[16] and Brook-type rearrangement of trifluoroacetylsilanes[17]

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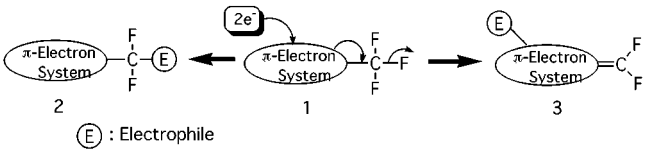
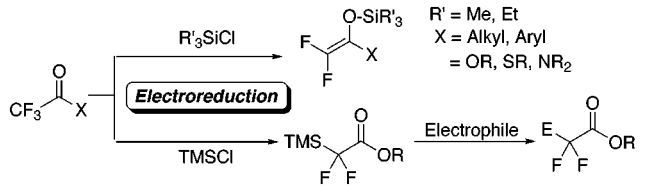


Figure 1.

Scheme 1



have been widely studied. Most of these defluorinations were achieved by 1,2-elimination-type reactions. Recently, we have found the reaction of (*N*-aryl)trifluoromethylimines with diethylzinc provides *N*-aryl-*N*-ethyl-*β*,*β*-difluoroenamines, which arise presumably via an electron transfer from the zinc reagent to the imine.[16] Taking into account the fact that an electron is a tiny and strong nucleophile, we came up with an idea that introduction of two electrons directly into the *π*-electron system attached to a CF_3 group would induce the pushing out of one of the fluorine atoms of a trifluoromethyl group,[18,19] and the subsequent trapping of the anionic intermediate with electrophiles on the *π*-system would provide **3**. The strategy of an electroreductive defluorination is illustrated in Figure 1. The transformation of **1** to **2** has already been reported for the trifluoromethylated aromatics by Perichon's group.[14,18]

In our previous communications,[20,21] we reported the one-pot syntheses of difluoroenol silyl ethers and *β*,*β*-difluoroenamines by electroreductive defluorination of trifluoromethyl ketones and imines, respectively. In this paper, we describe details of the selective electroreductive defluorination of trifluoromethyl ketones and trifluoroacetic acid derivatives, show the general applicability for the syntheses of *β*,*β*-difluoroketene silyl (*O*,*O*-, *O*,*S*-, and *O*,*N*-) acetals and 2,2-difluoro-2-trimethylsilyl acetates (Scheme 1),[22] and demonstrate the KF−CuI-promoted selective α-alkylation of the acetates.

Results and Discussion

Electroreductive Defluorination of Trifluoromethyl Ketones 4. Electroreduction of trifluoromethyl ketones **4** in the presence of TMSCl afforded difluoroenol silyl ethers **5**. Reaction conditions were surveyed using a model compound (**4a**), and the results are summarized in Table 1. Combination of a lead cathode and *n*-Bu_4NBr as a supporting electrolyte gave a high yield of **5a**. Temperature did not affect the yield of **5a** in the range of −20 to 30 °C (entries 3, 5, 6). A current density of around 10 mA/cm^2 or less was also effective (entries 3, 10, 11). Among the conditions examined, one of the critical factors for the yield of **5a** was the amount of TMSCl (entries 1−4). More than 3 equiv of TMSCl to **4a** was essential to obtain **5a** in a good yield. When only 1 equiv of TMSCl to **4a** was used, **5a** was not obtained (entry 1). This result suggests that trapping of a fluoride anion formed in situ from a trifluoromethyl group of **4a** was indispensable to prevent **5a** from desilylation. In fact, Me_3SiF was observed in ^{19}F NMR analysis of the crude reaction mixture after electrolysis, and in the case of 1 equiv of TMSCl to **4a**, the product **5a** was desilylated in situ and mostly transformed into the aldol condensation product **7** (Scheme 2).

This reaction can be applied to a variety of substituted trifluoromethyl ketones **4** (Table 2). Trimethylsilylenolates **5**[23,24] were unstable for isolation in a pure form for elemental analysis, and thus the yields of **5** were tentatively analyzed by ^{19}F NMR of two vinylic fluorines. However, triethylsilylenolates **6** that were prepared similarly were stable enough to be purified under silica gel column chromatography and analyzed by spectroscopies and elemental analysis. Both aromatic and aliphatic trifluoromethyl ketones provided **5** and **6** in good yields. In the case of *p*-chlorophenyl compound **4c**, the chlorine atom on the aromatic ring was partially replaced with a hydrogen atom under the reduction conditions and a mixture of **5c** (63%) and **5a** (19%) was obtained.[25] Reactions of heteroaromatic compounds **4d**−**f** and active methylene compound **4j** also gave the corresponding difluoroenol silyl ethers.

Electroreductive Defluorination of Trifluoroacetates 8. Difluoroenol silyl ethers **5** have been prepared by Reformatsky reaction of halodifluoroketones[7,12] and Brook-type rearrangement of trifluoroacetylsilanes.[17] Likewise, difluoroketene silyl acetals **9** have been prepared by Reformatsky reaction of halodifluoroacetates and have been employed in situ for Lewis acid catalyzed aldol reaction with aldehydes. However, the reported yields of **9** obtained by this method were not so good. Asymmetric aldol condensation of the Reformatsky reagent is useful; however, the reported enantioselectivity has been poor as a result of the unfavorable Lewis acid catalysis by the coexisted zinc(II) salt. Recently, Iseki succeeded in the isolation of pure **9a** (R = Et, 12% yield) by the repeated filtration of the zinc(II) salt and reported the first successful asymmetric Mukaiyama aldol reaction of **9a** by chiral Lewis acids.[7c,26]

Thus, a new method for the preparation of metal salt free difluoroketene silyl acetal or the alternative is required. The base-catalyzed deprotonation and *O*-silylation of difluoroacetate resulted in a mixture of the

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(18) Saboureau, C.; Troupel, M.; Sibille, S.; Perichon, J. *J. Chem. Soc., Chem. Commun.* **1989**, 1138.

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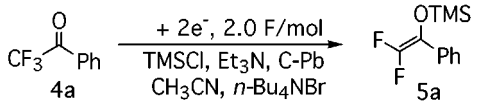
(23) Acetal **5** was not stable enough to perform elemental analysis. ^{19}F NMR (188 MHz) results follow. **5a**: ($CDCl_3$) *δ* 50.2 (d, *J* = 68 Hz), 61.9 (d, *J* = 68 Hz). **5b**: ($CDCl_3$) *δ* 48.3 (d, *J* = 73 Hz), 59.9 (d, *J* = 73 Hz). **5c**: (C_6D_6) *δ* 48.3 (d, *J* = 66 Hz), 59.9 (d, *J* = 66 Hz). **5d**: ($CDCl_3$) *δ* 51.8 (d, *J* = 63 Hz), 59.7 (d, *J* = 63 Hz). **5e**: (C_6D_6) *δ* 53.4 (d, *J* = 66 Hz), 60.0 (d, *J* = 66 Hz). **5f**: (C_6D_6) *δ* 56.2 (d, *J* = 52 Hz), 66.3 (d, *J* = 52 Hz). **5g**: ($CDCl_3$) *δ* 41.7 (d, *J* = 85 Hz), 55.6 (d, *J* = 85 Hz). **5h**: ($CDCl_3$) *δ* 51.8 (d, *J* = 63 Hz), 59.7 (d, *J* = 63 Hz). **5i**: ($CDCl_3$) *δ* 40.6 (d, *J* = 91 Hz), 54.4 (d, *J* = 91 Hz). **5j**: ($CDCl_3$) *δ* 43.4 (d, *J* = 80 Hz), 57.2 (d, *J* = 80 Hz).

(24) Ishihara, T.; Yamana, M.; Ando, T. *Tetrahedron Lett.* **1983**, *24*, 507.

(25) Volke, J., Liska, F., Eds. *Electrochemistry In Organic Synthesis*; Springer-Verlag: Berlin, 1994; pp 92−93.

(26) Iseki, K. *Tetrahedron* **1998**, *54*, 13887.

Table 1. Electroreductive Defluorination of Trifluoromethyl Ketone 4a



entry	temp. (°C)	TMSCl (mmol)	cathode material	supporting electrolyte	current density (mA/cm^2)	yield of **5a** (%)[a]
1	0	1.0	Pb	*n*-Bu_4NBr	15	0
2	0	2.0	Pb	*n*-Bu_4NBr	15	53
3	0	3.0	Pb	*n*-Bu_4NBr	15	80
4	0	5.0	Pb	*n*-Bu_4NBr	15	63
5	−20	3.0	Pb	*n*-Bu_4NBr	15	81
6	30	3.0	Pb	*n*-Bu_4NBr	15	80
7	0	3.0	Pb	$LiClO_4$	15	39
8	0	3.0	C	*n*-Bu_4NBr	15	77
9	0	3.0	Pt	*n*-Bu_4NBr	15	65
10	0	3.0	Pb	*n*-Bu_4NBr	4	78
11	0	3.0	Pb	*n*-Bu_4NBr	50	71

[a] Yields were determined by ^{19}F NMR analysis.

Scheme 2

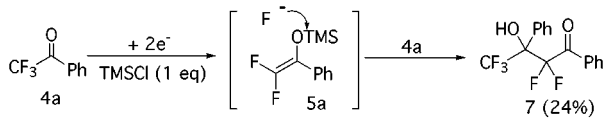
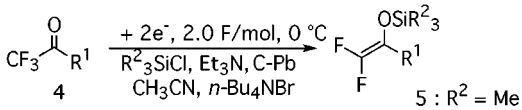


Table 2. Preparation of Difluoroenol Silyl Ethers 5 and 6

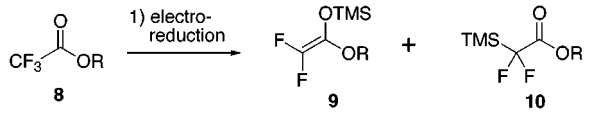


Compound	Substituent R^1	Yield (%)[a] 5[b] TMS	6[c] TES
a	Ph	(80)[d]	84
b	C_6H_4-OMe-*p*	(86)	72
c	C_6H_4-Cl-*p*	(63)[e]	49[e]
d		(72)	57
e		(74)	61
f		(70)	58
g		(74)	64
h	*n*-C_6H_{13}	(71)[d]	53
i	*c*-C_6H_{11}	(66)[d]	55
j	CH_2CO_2Et	(50)	42

[a] 3.0 mmol of TMSCl and 3.2 mmol of Et_3N to 4 (1 mmol) were used. [b] Yields were determined by ^{19}F NMR analysis.[21] [c] Isolated yields. [d] 5a, 5h and 5i. [22] [e] Chlorine of 4c was reductively replaced with hydrogen and 5a (R = Ph, 19%) and 6a (R = Ph, 16%)[23] were obtained as a side product, respectively.

Claisen product ($CF_3C(O)CF_2CO_2Et$) and ethyl 2,2-difluoro-2-trimethylsilyl acetate **10a**.[6f] Meanwhile, Stepanov et al. reported that electroreduction of **8a** (R = Et) provided a mixture of the Claisen product and **10a** with the use of low equivalents of TMSCl.[27]

Scheme 3



However, under the reaction condition (0 °C, 4 equiv of TMSCl) optimized for ketones **4**, electroreduction of **8b** afforded a mixture of *tert*-butyl difluoroketene silyl acetal **9b** (31%) and carbon silylated difluoroacetate **10b** (24%) (Scheme 3). Interestingly, the temperature was found to be critical. The formation of **10** predominated and no formation of **9** was observed at the higher temperature (50 °C) in the presence of a large excess of TMSCl [47% (65%), 58% (68%), and 62% (68%) for **9a**,[28] **9b**, and **9c**, respectively; yields in parentheses were determined by ^{19}F NMR].[22] The silyl migration from oxygen to carbon was observed at the higher temperature. In fact, a mixture of **9a** and **10a** (20:80) prepared by the electrolysis of **8a** at 0 °C was subjected to thermal isomerization at 50 °C for 3 h, affording **10a**[29] as a sole product. Under this reaction condition the self-condensation product was not obtained, but less than 10% of the acetals $CF_3CH(OTMS)OR$,[30] which might arise from the simple reduction of the carbonyl group of **8**, were accompanied in each case.

Recently, several types of compounds having an α,α-difluoro-α-trimethylsilylmethyl group[31] have been reported and used as effective CF_2 building blocks. The present carbon-silylated difluoro compounds **10** are promising building blocks because they are easily available, distillable, stable enough to be stored for a long time, and highly reactive in the presence of a fluoride ion. To

(27) Stepanov, A. A.; Minyaeva, T. V.; Martynov, B. I. *Tetrahedron Lett.* **1999**, *40*, 2203. Martynov, B. I.; Stepanov, A. A. cited in *Nobel Trends in Electroorganic Synthesis*; Torii, S., Ed.; Springer-Verlag: Tokyo, 1998; p 229.

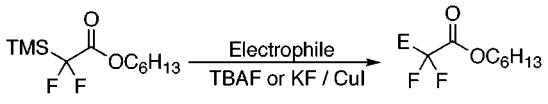
(28) **9a** and **9b** were already reported.[7c,29] **9c**: ^{19}F NMR (188 MHz, $CDCl_3$) δ 50.2 (d, J = 68 Hz), 61.9 (d, J = 68 Hz). Acetals **9** were not isolated as a result of their hydrolytic instability and were generated in situ for subsequent reaction.

(29) Britton, T. C. Jpn. Kokai Tokkyo Koho, Jp 7-188260, 1994.

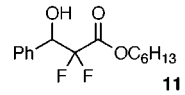
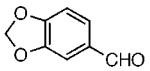
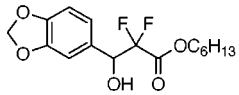
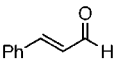
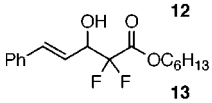
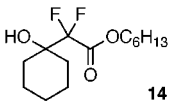
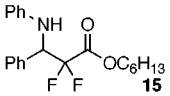
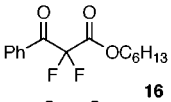
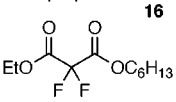
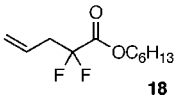
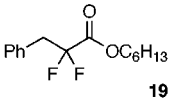
(30) Yields were determined by ^{19}F NMR analysis. The structure of $CF_3CH(OTMS)OC_2H_5$ was determined by authentic sample. ^{19}F NMR (188 MHz, $CDCl_3$) δ 78.7 (d, J = 3 Hz); ^1H NMR (200 MHz, $CDCl_3$) δ 1.29 (t, 3 H, J = 7.2 Hz), 4.14 (q, 2 H, J = 7.2 Hz), 5.48−5.56 (m, 1 H).

(31) Prakash, G. K. S.; Yudin, A. K. *Chem. Rev.* **1997**, *77*, 7577 and references therein.

Table 3. Reaction of *n*-Hexyl α-Trimethylsilyl-α,α-difluoroacetate (10c) with Various Electrophiles and Halides



10c **11-19**

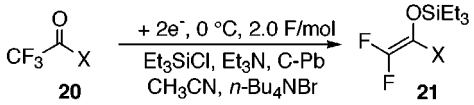
Entry	Substrate	Method	Product	Yield (%)
1	PhCHO	A	 **11**	82
2		B	 **12**	85
3		A	 **13**	76
4		B	 **14**	92
5		B	 **15**	83
6		B	 **16**	60
7		A	 **17**	45
8		B	 **18**	85
9	$PhCH_2Br$	B	 **19**	79

Method A : TBAF was used as a fluoride ion source. Method B: KF and CuI were used.

explore the reactivity of 2,2-difluoro-2-trimethylsilyl acetates, **10c** was subjected to the TBAF-catalyzed C−C bond formation with electrophiles such as aldehydes, ketones, acylhalides, imine, and alkylhalides and afforded the desired alkylated products (Table 3). In entry 2, reaction with cinnamaldehyde gave the 1,2-adduct selectively. Taguchi's group reported that the Lewis acid-catalyzed reaction of ketene silyl acetal afforded a mixture of 1,2- and 1,4-adducts.[32] Meanwhile, Iseki's group reported that the Reformatsky reaction of halodifluoroacetates afforded 1,2-adducts only.[7c] So, it can be said that the reactivity of 2,2-difluoro-2-trimethylsilyl acetates are closer to halodifluoroacetates than the ketene silyl acetals. Reactions of **10c** with acylhalides and imine were also successful (entries 5−7). α-Alkylation of **10c** in the presence of KF and CuI was successfully achieved with allyl and benzylhalides. However, *n*-butylbromide was not a good electrophile for this purpose. Only *n*-butyliodide afforded the alkylated product in a very poor yield.[33] Most of the side product was a self-condensation product ($CF_2HC(O)CF_2CO_2C_6H_{13}$). The

(32) Kitagawa, O.; Hashimoto, A.; Kobayashi, Y.; Taguchi, T. *Chem. Lett.* **1990**, 1307.

Table 4. Preparation of Difluoroketene Silyl (*O, S*- and *O, N*-) Acetals 21



20 **21**

Compound	X	Yield of **22** (%)[a]
20a	S^tBu	54 (72)[b]
20b	SPh	52 (70)
20c	NPh_2	45 (74)

[a] 3.0 mmol of TMSCl and 3.2 mmol of Et_3N to **20** (1 mmol) were used. [b] Yields in the parenthesis were determined by ^{19}F NMR analysis.

α-alkylation of Reformatsky-type reagent with benzyl- and crotylbromides was achieved only with iododifluoroacetate, and the reaction of bromo- and/or chlorodifluoroacetate was unsuccessful.[34]

Electroreductive Defluorination of Trifluoroacetate Equivalents, (*O,S*- and *O,N*-) Esters 20. The successful transformation of trifluoroacetates to 2,2-difluoro-2-trimethylsilyl acetates prompted us to seek the similar transformation of trifluoroacetamide and trifluorothioacetate. Wigel reported the preparation of difluoroketene silyl (*O,S*)-acetal by LDA-catalyzed silylation of difluoroethanethioate in the presence of TMSCl.[6f] Preparation of the related compounds, $CF_2{=}C(SPh)_2$,[6e] $CF_2{=}C(-S-CH_2-CH_2-S-)$,[35] and $CF_2{=}C(NMe)_2$[6d,36] have also been reported. All of these compounds have a unique reactivity and have been utilized as building blocks for bioactive compounds.

Interestingly, it was found that almost the same electrolysis conditions as for trifluoromethyl ketones are applicable for the preparation of ketene silyl (*O,S*-, and *O,N*-) acetals. As demonstrated in Table 4, the electrochemical reaction of thioesters **20** (X = SR) and amide **20** ($X = NPh_2$) afforded the corresponding difluoro ketene silyl acetals in good yields.

Conclusion

In summary, a variety of difluoroenol ethers, difluoroketene silyl (*O,O*-, *O,S*-, and *O,N*-) acetals, and 2,2-difluoro-2-trimethylsilyl acetates were prepared electroreductively from trifluoromethyl carbonyl compounds. Alkylations of the 2,2-difluoro-2-trimethylsilyl acetates with various electrophiles were successful. These CF_2 building blocks are expected to be applied in the synthesis of useful CF_2 compounds. The present electrochemical reaction is applicable to a useful preparation of the various difluoromethylene compounds.

Experimental Section

General Procedure. Acetonitrile, Et_3N, TMSCl, and TESCl were freshly distilled from CaH_2. THF was distilled from Na and benzophenone. Column chromatography was carried out

(33) Spectral data of *n*-hexyl 2,2-difluorohexanoate: 17% yield (determined by ^{19}F NMR analysis); ^{19}F NMR (188 MHz, $CDCl_3$) δ 55.9 (t, J = 18 Hz); ^1H NMR (200 MHz, $CDCl_3$) δ 0.86 (m, 6 H), 1.33−1.53 (m, 10 H), 1.54−1.74 (m, 2 H), 1.93−2.17 (m, 2 H), 4.25 (t, 2 H, J = 6.9 Hz).

(34) Kitagawa, O.; Taguchi, T.; Kobayashi, Y. *Chem. Lett.* **1989**, 389.

(35) Grimbert, Y.; Moradpour, T. A.; Dive, G.; Dehareng, D.; Lahil, K. *J. Org. Chem.* **1993**, *58*, 4865.

(36) Xu, Y.; Dolbier, W. R., Jr. *J. Org. Chem.* **1997**, *62*, 1576.

with E. Merck silica gel (Kieselgel 60, 230−400 mesh) and alumina (about 300 mesh). The chemical shifts of ^{1}H and ^{19}F NMR spectra are reported in δ ppm values relative to TMS (0.00 ppm for ^{1}H NMR) and C_6F_6 (0.0 ppm for ^{19}F NMR) with $CDCl_3$, C_6D_6, and DMSO-d_6 as solvents. NMR yields were obtained with ^{19}F NMR using 1,3-bistrifluoromethylbenzene as an internal standard. Coupling constants (J) are reported in Hz.

General Procedure for Electroreductive Defluorination of Trifluoromethyl Ketones, Trifluorothioacetates, and Trifluoromethylamide in the Presence of Chlorotriethylsilane. The electroreductive defluorination of trifluoromethyl compounds **4** and **20** (1 mmol) was carried out by using a Pb cathode (1 × 2 cm^2) and a carbon anode in anhydrous acetonitrile (7 + 7 mL) containing *n*-Bu_4NBr (1.29 g, 4 mmol) and TESCl (452 mg, 3 mmol) in an H-type divided cell. A constant current of 30 mA was passed at 0 °C under an argon atmosphere until **4** and **20** were consumed (2 F/mol). After the electrolysis, Et_3N (303 mg, 3 mmol) was added. The reaction mixture was concentrated in vacuo and chromatographed quickly on silica gel pretreated with Et_3N (hexane, grade to 10% AcOEt/hexane) to give β,β-difluoroenol triethylsilyl ethers **6** and **21** as colorless oils.

1-Triethylsiloxy-2,2-difluoro-1-phenylethene (6a). Colorless oil: (227 mg, 84%); IR (neat) ν_{max} 1730 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.65 (q, 6 H, J = 7.8 Hz), 0.94 (t, 9 H, J = 7.8 Hz), 7.25−7.51 (m, 5 H); ^{19}F NMR (188 MHz,$CDCl_3$) δ 49.3 (d, 1 F, J = 69 Hz), 61.1 (d, 1 F, J = 69 Hz); GC−MS m/z 270 (M$^+$). Anal. Calcd for $C_{14}H_{20}F_2OSi$: C, 62.19; H, 7.46. Found: C, 62.18; H, 7.08.

1-Triethylsiloxy-2,2-difluoro-1-(*p*-methoxyphenyl)-ethene (6b). Colorless oil: (216 mg, 72%); IR (neat) ν_{max} 1730 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.67 (q, 6 H, J = 7.3 Hz), 0.97 (t, 9 H, J = 7.3 Hz), 3.83 (s, 3 H), 6.92 (d, 2 H, J = 8.3 Hz), 7.43 (d, 2 H, J = 8.3 Hz); ^{19}F NMR (188 Mz, $CDCl_3$) δ 47.4 (d, 1 F, J = 73 Hz), 59.3 (d, 1 F, J = 73 Hz); GC−MS m/z 300 (M$^+$). Anal. Calcd for $C_{15}H_{22}F_2O_2Si$: C, 59.97; H, 7.38. Found: C, 59.69; H, 7.77.

1-Triethylsiloxy-2,2-difluoro-1-(*p*-chlorophenyl)-ethene (6c). Colorless oil: (149 mg, 49%); IR (neat) ν_{max} 1730 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, DMSO-d_6) δ 0.63 (q, 6 H, J = 7.3 Hz), 0.91 (t, 9 H, J = 7.3 Hz), 7.48 (d, 2 H, J = 8.9 Hz), 7.55 (d, 2 H, J = 8.9 Hz); ^{19}F NMR (188 MHz, $CDCl_3$) δ 50.2 (d, 1 F, J = 67 Hz), 62.0 (d, 1 F, J = 67 Hz); GC−MS m/z 304 (M$^+$). Anal. Calcd for $C_{14}H_{19}ClF_2OSi$: C, 55.16; H, 6.28. Found: C, 55.34; H, 6.32.

2-(1-Triethylsiloxy-2,2-difluoroethenyl)furan (6d). Colorless oil: (148 mg, 57%); IR (neat) ν_{max} 1736 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.71 (q, 6 H, J = 8.1 Hz), 0.95 (t, 9 H, J = 8.1 Hz), 6.39−6.40 (m, 1 H), 6.44−6.46 (m, 1 H), 7.43 (br. s, 1 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 51.5 (d, 1 F, J = 64 Hz), 59.4 (d, 1 F, J = 64 Hz); GC−MS m/z 260 (M$^+$). Anal. Calcd for $C_{12}H_{18}F_2O_2Si$: C, 55.36; H, 6.97. Found: C, 55.10; H, 7.23.

2-(1-Triethylsiloxy-2,2-difluoroethenyl)thiophene (6e). Colorless oil: (168 mg, 61%); IR (neat) ν_{max} 1728 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.65 (q, 6 H, J = 8.1 Hz), 0.91 (t, 9 H, J = 8.1 Hz), 6.93−6.98 (m, 1 H), 7.02−7.04 (m, 1 H), 7.19−7.24 (m, 1 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 52.6 (d, 1 F, J = 66 Hz), 59.2 (d, 1 F, J = 66 Hz); GC−MS m/z 276 (M$^+$). Anal. Calcd for $C_{12}H_{18}F_2OSSi$: C, 52.14; H, 6.56. Found: C, 51.94; H, 6.34.

2-(1-Triethylsiloxy-2,2-difluoroethenyl)pyridine (6f). Colorless oil: (157 mg, 58%); IR (neat) ν_{max} 1724 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.64 (q, 6 H, J = 8.1 Hz), 0.89 (t, 9 H, J = 8.0 Hz), 7.08−7.16 (m, 1 H), 7.40−7.46 (m, 1 H), 7.59−7.67 (m, 1 H), 8.54−8.57 (m, 1 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 54.3 (d, 1 F, J = 54 Hz), 65.5 (d, 1 F, J = 54 Hz); GC−MS m/z 242 (M$^+$ − Et). Anal. Calcd for $C_{13}H_{19}F_2NOSi$: C, 57.54; H, 7.06. Found: C, 57.34; H, 7.28.

2-Triethylsiloxy-1,1-difluoro-4-phenylbutene (6g). Colorless oil: (191 mg, 64%); IR (neat) ν_{max} 1768 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.70 (q, 6 H, J = 7.8 Hz), 1.01 (t, 9 H, J = 7.8 Hz), 2.30−2.41 (m, 2 H), 2.82 (t, 2 H, J = 8.0 Hz), 7.18−7.34 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.4 (d, 1 F, J = 85 Hz), 55.3 (d, 1 F, J = 85 Hz); GC−MS m/z 298 (M$^+$). Anal. Calcd for $C_{16}H_{24}F_2OSi$: C, 64.39; H, 8.11. Found: C, 64.09; H, 8.34.

2-Triethylsiloxy-1,1-difluoro-1-octene (6h). Colorless oil: (147 mg, 53%); IR (neat) ν_{max} 1768 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.66 (q, 6 H, J = 7.8 Hz), 0.88 (t, 3 H, J = 6.7 Hz), 0.97 (t, 9 H, J = 7.8 Hz), 1.28−1.48 (m, 8 H), 1.97−2.09 (m, 2 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 40.6 (d, 1 F, J = 85 Hz), 54.6 (d, 1 F, J = 85 Hz); GC−MS m/z 278 (M$^+$). Anal. Calcd for $C_{14}H_{28}F_2OSi$: C, 60.39; H, 10.13. Found: C, 60.46; H, 10.50.

1-Cyclohexyl-1-triethylsiloxy-2,2-difluoroethene (6i). Colorless oil: (152 mg, 55%); IR (neat) ν_{max} 1758 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.67 (q, 6 H, J = 7.8 Hz), 0.98 (t, 9 H, J = 7.8 Hz), 1.14−1.79 (m, 10 H), 2.04−2.21 (m, 1 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 40.1 (d, 1 F, J = 91 Hz), 53.9 (d, 1 F, J = 91 Hz); GC−MS m/z 276 (M$^+$). Anal. Calcd for $C_{14}H_{26}F_2OSi$: C, 60.83; H, 9.48. Found: C, 60.44; H, 9.66.

Ethyl 3-triethylsiloxy-4,4-difluoro-3-butenoate (6j). Colorless oil: (118 mg, 42%); IR (neat) ν_{max} 1748 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.66 (q, 6 H, J = 7.8 Hz), 0.95 (t, 9 H, J = 7.8 Hz), 1.26 (t, 3 H, J = 7.2 Hz), 3.06−3.09 (m, 2 H), 4.16 (q, 2 H, J = 7.2 Hz); ^{19}F NMR (188 MHz, $CDCl_3$) δ 43.2 (d, 1 F, J = 81 Hz), 57.0 (d, 1 F, J = 81 Hz); GC−MS m/z 251 (M$^+$ − Et). Anal. Calcd for $C_{12}H_{22}F_2O_3Si$: C, 51.40; H, 7.91. Found: C, 51.13; H, 8.29.

2,2,4,4,4-Pentafluoro-3-hydroxy-1,3-diphenyl-1-butanone (7). The electroreductive defluorination of trifluoromethyl ketone **4a** (174 mg, 1 mmol) was carried out by using a Pb cathode (1 × 2 cm^2) and a carbon anode in anhydrous acetonitrile (7 + 7 mL) containing *n*-Bu_4NBr (1.29 g, 4 mmol), Et_3N (101 mg, 1 mmol), and TMSCl (109 mg, 1 mmol) in an H-type divided cell. A constant current of 30 mA (1.5 F/mol) was passed at 0 °C under an argon atmosphere. The reaction mixture was concentrated in vacuo and chromatographed on silica gel (5% AcOEt/hexane as an eluent) to give **7**. Colorless oil: (79 mg, 24%); IR (neat) ν_{max} 3492 (OH), 1696 (C═O) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 4,86 (s, 1 H), 7.36−7.49 (m, 5 H), 7.60−7.72 (m, 3 H), 7.89−7.94 (m, 2 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 55.9 (q, 1 F, J = 12 Hz), 56.2 (q, 1 F, J = 9.7 Hz), 88.4 (t, 3 F, J = 11 Hz). Anal. Calcd for $C_{16}H_{11}F_5O_2$: C, 58.19; H, 3.36. Found: C, 58.09; H, 3.57.

1-*tert*-Butylthio-1-triethylsiloxy-2,2-difluoroethene (21a). Following the general procedure, crude product was purified using alumina column chromatography with hexane as an eluent. Colorless oil: (152 mg, 54%); IR (neat) ν_{max} 1714 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.72 (q, 6 H, J = 8.0 Hz), 0.98 (t, 9 H, J = 8.1 Hz), 1.36 (s, 9 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 58.2 (d, 1 F, J = 47 Hz), 70.0 (d, 1 F, J = 47 Hz); GC−MS m/z 282 (M$^+$). Anal. Calcd for $C_{12}H_{24}F_2OSSi$: C, 51.03; H, 8.56. Found: C, 51.25; H, 8.74.

1-Triethylsiloxy-1-phenylthio-2,2-difluoroethene (21b). Colorless oil: (157 mg, 52%); IR (neat) ν_{max} 1722 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, C_6D_6) δ 0.62 (q, 6 H, J = 8.1 Hz), 0.92 (t, 9 H, J = 8.1 Hz), 6.88−7.04 (m, 3 H) 7.30−7.34 (m, 2 H); ^{19}F NMR (188 MHz, C_6D_6) δ 56.5 (d, 1 F, J = 49 Hz), 69.4 (d, 1 F, J = 49 Hz); GC−MS m/z 302 (M$^+$). Anal. Calcd for $C_{14}H_{20}F_2OSSi$: C, 55.60; H, 6.66. Found: C, 55.44; H, 6.39.

***N,N*-Diphenyl-1-triethylsiloxy-2,2-difluoroethenylamine (21c).** Colorless oil: (162 mg, 45%); IR (neat) ν_{max} 1770 (C═C) cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.52 (q, 6 H, J = 7.5 Hz), 0.84 (t, 9 H, J = 7.5 Hz), 6.98−7.12 (m, 6 H), 7.23−7.32 (m, 4 H); ^{19}F NMR (56.5 MHz, $CDCl_3$) δ 44.4 (d, 1 F, J = 72 Hz), 52.3 (d, 1 F, J = 72 Hz); GC−MS m/z 247 (M$^+$ − $SiEt_3$). Anal. Calcd for $C_{20}H_{25}F_2NOSi$: C, 66.45; H, 6.97; N, 3.87. Found: C, 66.31; H, 7.22; N, 3.47.

Electroreductive Defluorination of Trifluoroacetate 8 in the Presence of TMSCl and Lewis Acid Catalyzed Mukaiyama Aldol Reaction of 9. The electroreductive defluorination of trifluoroacetate **8** (1 mmol) was carried out by using a Pb cathode (1 × 2 cm^2) and a carbon anode in anhydrous acetonitrile (7 + 7 mL) containing *n*-Bu_4NBr (1.29 g, 4 mmol), Et_3N (505 mg, 5 mmol), and TMSCl (545 mg, 5 mmol) in an H-type divided cell. A constant current of 30 mA (2 F/mol) was passed at 0 °C under an argon atmosphere. After

the electrolysis, the product β,β-difluoroketene trimethylsilyl acetals **9** were determined by ^{19}F NMR, and **9** was extracted with pentane from acetonitrile solution (2 mL × 5). To a solution of benzaldehyde (106 mg, 1 mmol) and $TiCl_4$ (1.0 mL of a 1.0 M solution in CH_2Cl_2) in dry CH_2Cl_2 (2 mL) was added the extracted pentane solution, and the mixture was stirred at −78 °C under an argon atmosphere for 1.5 h. The reaction mixture was allowed to warm to room temperature, stirred for 5 h, and quenched with saturated aqueous NH_4Cl. The organic substrates were extracted with ether (4 mL × 5). The organic layer was washed with water and brine, dried over anhydrous $MgSO_4$, concentrated in vacuo, and chromatographed on silica gel (25% AcOEt/hexane) to give **11**.

Ethyl 2,2-Difluoro-3-hydroxy-3-phenylpropanoate (11a).[7c] Colorless oil: (24 mg, 10%); IR (neat) 3475, 1762 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 1.26 (t, 3 H, J = 7.2 Hz), 3.19 (br, 1 H), 4.27 (q, 2 H, J = 7.2 Hz), 5.15 (ddd, 1 H, J = 5.4 Hz, J = 8.5 Hz, J = 15.2 Hz), 7.36−7.46 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.0 (dd, 2 F, J_{FH} = 15 Hz, J_{FF} = 261 Hz), 48.8 (dd, 2 F, J_{FH} = 8 Hz, J_{FF} = 261 Hz).

***tert*-Butyl 2,2-Difluoro-3-hydroxy-3-phenylpropanoate (11b).** Colorless crystal: (69 mg, 27%); IR (neat) 3508, 1754 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 1.45 (s, 9 H), 2.72 (d, 1 H, J = 5.4 Hz), 5.05−5.18 (m, 1 H), 7.35−7.46 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 42.9 (dd, 2 F, J_{FH} = 13 Hz, J_{FF} = 258 Hz), 47.6 (dd, 2 F, J_{FH} = 9 Hz, J_{FF} = 258 Hz); GC−MS m/z 258 (M^+). Anal. Calcd for $C_{13}H_{16}F_2O_3$: C, 60.46; H, 6.24. Found: C, 60.29; H, 6.62.

***n*-Hexyl 2,2-Difluoro-3-hydroxy-3-phenylpropanoate (11c).** Colorless oil: (37 mg, 13%); IR (neat) 3532, 1760 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, 3 H, J = 6.8 Hz), 1.26−1.41 (m, 6 H), 1.58−1.68 (m, 2 H), 2.69 (d, 1 H, J = 5.4 Hz), 4.23 (t, 2 H, J = 6.8 Hz), 5.16 (ddd, 1 H, J = 5.4 Hz, J = 8.5 Hz, J = 15.2 Hz), 7.36−7.46 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.6 (dd, 2 F, J_{FH} = 15 Hz, J_{FF} = 262 Hz), 47.8 (dd, 2 F, J_{FH} = 9 Hz, J_{FF} = 262 Hz); GC−MS m/z 286 (M^+). Anal. Calcd for $C_{15}H_{20}F_2O_3$: C, 62.92; H, 7.04. Found: C, 62.58; H, 7.30.

Preparation of 2,2-Difluoro-2-trimethylsilyl Acetate (10). The electroreductive defluorination of trifluoroacetate **8** (5 mmol) was carried out by using a Pb cathode (2 × 5 cm^2) and a carbon anode in anhydrous acetonitrile (60 mL) containing n-Bu_4NBr (3.85 g, 12 mmol), Et_3N (2.12 g, 21 mmol), and TMSCl (2.17 g, 20 mmol) in an H-type divided cell. A constant current of 80 mA (2 F/mol) was passed at 50 °C under an argon atmosphere. After the electrolysis, the reaction mixture was concentrated in vacuo, and the residue was distilled under reduced pressure to give **10**.

Ethyl 2,2-Difluoro-2-trimethylsilyl Acetate (10a). Colorless oil: (461 mg, 47%); bp 40 °C/45 mmHg (Kugelrohr); IR (neat) ν_{max} 1756 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.23 (s, 9 H), 1.34 (t, 3 H, J = 7.2 Hz), 4.31 (q, 2 H, J = 7.2 Hz); ^{19}F NMR (188 MHz, $CDCl_3$) δ 38.5 (s, 2 F); GC−MS m/z 196 (M^+). Anal. Calcd for $C_7H_{14}F_2O_2Si$: C, 42.84; H, 7.19. Found: C, 42.97; H, 7.45.

***tert*-Butyl 2,2-Difluoro-2-trimethylsilyl Acetate (10b).** Colorless oil: (650 mg, 58%); bp 50 °C/20 mmHg (Kugelrohr); IR (neat) ν_{max} 1760 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.22 (s, 9 H), 1.52 (s, 9 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 38.9 (s, 2 F); GC−MS m/z 224 (M^+). Anal. Calcd for $C_9H_{18}F_2O_2Si$: C, 48.19; H, 8.09. Found: C, 48.33; H, 8.01.

***n*-Hexyl 2,2-Difluoro-2-trimethylsilyl Acetate (10c).** Colorless oil: (781 mg, 62%); bp 80 °C/2 mmHg (Kugelrohr); IR (neat) ν_{max} 1756 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.23 (s, 9 H), 0.89 (t, 3 H, J = 6.6 Hz), 1.30−1.41 (m, 6 H), 1.62−1.72 (m, 2 H), 4.23 (t, 2 H, J = 6.8 Hz); ^{19}F NMR (188 MHz, $CDCl_3$) δ 38.7 (s, 2 F); GC−MS m/z 152 ($M^+ - OC_6H_{12}$), 73 ($M^+ - CF_2CO_2C_6H_{13}$). Anal. Calcd for $C_{11}H_{22}F_2O_2Si$: C, 52.35; H, 8.79. Found: C, 52.04; H, 8.99.

General Procedure for the Reaction of 2,2-Difluoro-2-trimethylsilyl Acetate with Electrophile. To a solution of **10c** (252 mg, 1 mmol) and benzaldehyde (3.18 mg, 3 mmol) in THF (1.5 mL) at −78 °C was added TBAF (1.0 mL of a 1.0 M solution in THF) dropwise. After it stirred for 1 h at −78 °C, the reaction mixture was filtered through a pad of Florisil to remove salts. The filtrate was concentrated in vacuo. Chromatography on silica gel (10% diethyl ether/hexane) provided **11c** (235 mg, 82%).

***n*-Hexyl 2,2-Difluoro-3-hydroxy-3-piperonylpropanoate (12).** A solution of **10c** (252 mg, 1 mmol), piperonal (450 mg, 3 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 8 h at 70 °C. The reaction mixture was filtered through a pad of Florisil to remove salts. The filtrate was concentrated in vacuo. Chromatography of the residue on silica gel provided **12**. Colorless oil: (281 mg, 85%); IR (neat) ν_{max} 1756 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, 3 H, J = 5.5 Hz), 1.20−1.40 (m, 6 H), 1.59−1.75 (m, 2 H), 2.61−2.72 (br, 1 H), 4.24 (t, 2 H, J = 5.8 Hz) 5.01−5.15 (m, 1 H), 5.99 (s, 2 H), 6.77−6.98 (m, 3 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.4 (dd, 2 F, J_{FH} = 15 Hz, J_{FF} = 259 Hz), 47.8 (dd, 2 F, J_{FH} = 8 Hz, J_{FF} = 259 Hz); GC−MS m/z 330 (M^+). Anal. Calcd for $C_{16}H_{20}F_2O_5$: C, 58.18; H, 6.10. Found: C, 58.12; H, 6.19.

***n*-Hexyl 2,2-Difluoro-3-hydroxy-5-phenyl-4-pentenoate (13).** To a solution of **10c** (252 mg, 1 mmol) and cinnamaldehyde (396 mg, 3 mmol) in THF (1.5 mL) at −78 °C was added TBAF (1.0 mL of a 1.0 M solution in THF) dropwise. After the mixture stirred for 1 h at −78 °C and 3 h at room temperature, the usual workup procedure provided **13**. Colorless oil: (237 mg, 76%); IR (neat) ν_{max} 3476 (OH), 1764 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.87 (t, 3 H, J = 6.9 Hz), 1.25−1.34 (m, 6 H), 1.61−1.72 (m, 2 H), 2.41 (br, 1 H), 4.29 (t, 2 H, J = 6.6 Hz), 4.63−4.82 (m, 1 H), 6.24 (dd, 1 H, J = 6.6 Hz, J = 15.8 Hz), 6.81 (d, J = 15.8 Hz), 7.26−7.43 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.3 (dd, 2 F, J_{FH} = 13 Hz, J_{FF} = 263 Hz), 47.5 (dd, 2 F, J_{FH} = 8 Hz, J_{FF} = 263 Hz); GC−MS m/z 312 (M^+). Anal. Calcd for $C_{17}H_{22}F_2O_3$: C, 65.37; H, 7.10. Found: C, 65.06; H, 7.41.

***n*-Hexyl 2,2-Difluoro-2-(1-hydroxycyclohexyl)acetate (14).** A solution of **10c** (252 mg, 1 mmol), cyclohexanone (490 mg, 5 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 20 h at 60 °C; the usual workup procedure of the mixture provided **14**. Colorless oil: (256 mg, 92%); IR (neat) ν_{max} 3528 (OH), 1762 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, 3 H, J = 5.9 Hz), 1.13−1.41 (m, 8 H), 1.54−1.74 (m, 10 H), 2.02 (br, 1 H), 4.27 (t, 2 H, J = 6.7 Hz); ^{19}F NMR (188 MHz, $CDCl_3$) δ 41.9 (s, 2 F). Anal. Calcd for $C_{14}H_{24}F_2O_3$: C, 60.41; H, 8.69. Found: C, 60.28; H, 9.07.

***n*-Hexyl 3-(*N*-Phenyl)amino-2,2-difluoro-3-phenylpropanoate (15).** A solution of **10c** (252 mg, 1 mmol), imine (272 mg, 1.5 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 10 h at 70 °C; the usual workup procedure of the mixture provided **15**. Colorless oil: (299 mg, 83%); IR (neat) ν_{max} 3400 (NH), 1770 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.79 (t, 3 H, J = 6.9 Hz), 1.12−1.26 (m, 6 H), 1.45−1.57 (m, 2 H), 4.14 (t, 2 H, J = 6.9 Hz), 4.94−5.11 (m, 1 H), 6.48−6.70 (m, 3 H), 7.00−7.09 (m, 2 H), 7.25−7.39 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 42.4 (dd, 2 F, J_{FH} = 7 Hz, J_{FF} = 256 Hz), 52.6 (dd, 2 F, J_{FH} = 19 Hz, J_{FF} = 256 Hz). Anal. Calcd for $C_{21}H_{25}F_2NO_2$: C, 69.79; H, 6.97; N, 3.88. Found: C, 69.69; H, 7.25; N, 3.99.

***n*-Hexyl 2,2-Difluoro-3-oxo-3-phenylpropanoate (16).** A solution of **10c** (252 mg, 1 mmol) and benzoyl chloride (422 mg, 3 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 8 h at 60 °C; the usual workup procedure of the mixture provided **16**. Colorless oil: (170 mg, 60%); IR (neat) ν_{max} 1776 (C=O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.79 (t, 3 H, J = 6.8 Hz), 1.13−1.24 (m, 6 H), 1.55−1.62 (m, 2 H), 4.25 (t, 2 H, J = 6.8 Hz), 7.19−7.62 (m, 3 H), 7.99−8.03 (m, 2 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 54.1 (S, 2 F); GC−MS m/z 355 (M^+). Anal. Calcd for $C_{15}H_{18}F_2O_3$: C, 63.37; H, 6.38. Found: C, 63.04; H, 6.63.

Ethyl *n*-Hexyl 2,2-Difluoromalonate (17). To a solution of **10c** (252 mg, 1 mmol) and ethylchloroformate (543 mg, 5 mmol) in THF (1.5 mL) at −45 °C was added TBAF (2.0 mL

of a 1.0 M solution in THF) dropwise. After stirred for 20 h at −45 °C, the usual workup procedure of the mixture provided **17**. Colorless oil: (113 mg, 45%); IR (neat) ν_{max} 1784 (C═O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.92 (t, 3 H, J = 6.8 Hz), 1.26−1.40 (m, 9 H), 1.66−1.79 (m, 2 H), 4.29−4.42 (m, 4 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 49.6 (s, 2 F). Anal. Calcd for $C_{11}H_{18}F_2O_4$: C, 52.38; H, 7.19. Found: C, 52.25; H, 7.36.

***n*-Hexyl 2,2-Difluoro-4-pentenoate (18).** A solution of **10c** (252 mg, 1 mmol), allyl chloride (383 mg, 5 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 5 h at 45 °C; the usual workup procedure of the mixture provided **18**. Colorless oil: (187 mg, 85%); IR (neat) ν_{max} 1774 (C═O), 1470 (C═C) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, 3 H, J = 6.6 Hz), 1.12−1.46 (m, 6 H), 1.62−1.74 (m, 2 H), 2.74−2.94 (m, 2 H), 4.25 (t, 2 H, J = 6.7 Hz), 5.15−5.30 (m, 2 H), 5.68−5.89 (m, 1 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 56.3 (t, 2 F, J_{FH} = 15 Hz). Anal. Calcd for $C_{11}H_{18}F_2O_2$: C, 59.98; H, 8.24. Found: C, 59.62; H, 8.15.

***n*-Hexyl 2,2-Difluoro-3-phenylpropanoate (19).** A solution of **10c** (252 mg, 1 mmol), benzylbromide (380 mg, 3 mmol), KF (70 mg, 1.2 mmol), and CuI (285 mg, 1.5 mmol) in DMF (1.5 mL) under an argon atmosphere was stirred for 8 h at 70 °C; the usual workup procedure of the mixture provided **19**. Colorless oil: (214 mg, 79%); IR (neat) ν_{max} 1770 (C═O) cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, 3 H, J = 6.8 Hz), 1.12−1.41 (m, 6 H), 1.56−1.72 (m, 2 H), 3.38 (t, 2 H, J = 16.4 Hz), 4.17 (t, 2 H, J = 6.6 Hz) 7.21−7.34 (m, 5 H); ^{19}F NMR (188 MHz, $CDCl_3$) δ 57.2 (t, 2 F, J_{HF} = 17 Hz); GC−MS m/z 270 (M^+). Anal. Calcd for $C_{15}H_{20}F_2O_2$: C, 66.65; H, 7.46. Found: C, 66.75; H, 7.24.

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