

RESEARCH ARTICLE

View Article Online

View Journal | View Issue

Cite this: *Org. Chem. Front.*, 2022, 9, 342Received 2nd November 2021,
Accepted 22nd November 2021

DOI: 10.1039/d1qo01633d

rsc.li/frontiers-organic

Electrophilic *N*-trifluoromethylthiophthalimide as a fluorinated reagent in the synthesis of acyl fluorides†

Chen Zhu, ‡ Serik Zhumagazy, ‡ Huifeng Yue * and Magnus Rueping *

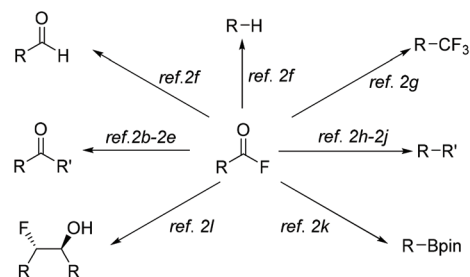
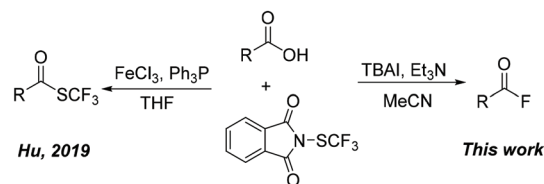
Herein we report the deoxygenated fluorination of readily available carboxylic acids. A series of acyl fluorides have been synthesized using shelf-stable *N*-trifluoromethylthiophthalimide as a fluorinated reagent for the first time. Scale-up reactions and sequential cross-couplings were performed successfully to demonstrate the practicability of this fluorination protocol.

Fluorine-containing molecules are one class of the most important organic compounds due to the unique character of the fluorine atom in modulating the chemical and biological properties such as metabolic stability, lipophilicity, and bio-availability.¹ Therefore, the development of methods to access such compounds is always a research focus for organic chemists. In this context, acyl fluorides represent intriguing targets that play an important role in organic synthesis. Due to the outstanding balance between stability and reactivity, acyl fluorides were widely employed as versatile synthons in different types of organic transformations (Scheme 1a).² Also, acyl fluorides could be used for the activation of silyl enol ethers or other silicon species in the presence of a Lewis base.³ Conventional methods to access acyl fluorides depend on the halogen exchange reaction of acyl chlorides with “F” sources.⁴ Recent advances were mainly focused on the deoxy-fluorination of readily available carboxylic acids with various fluorinated reagents (e.g., CF₃SO₂OCF₃,⁵ PPh₃/Selectfluor,⁶ Me₄NSCF₃,⁷ cyanuric fluoride,⁸ HF-Pyridine/DCC,⁹ sulphur tetrafluoride derivatives,¹⁰ and Carpino’s salt TFFH¹¹). Notably, Shibata and coworkers developed a general and practical method to prepare acyl fluorides, in which acids, aldehydes, and alcohols all could be transformed into acyl fluorides by using inexpensive reagents, TCCA and CsF.¹² In addition, acyl fluorides were skillfully accessed *via* selective C–C bond cleavage using DAST or its derivatives as fluorination reagents.¹³ Although these achievements provide good alternatives, most of them suffered from some drawbacks, mainly including high

reaction temperature or the use of fluorinated reagents that are toxic, unstable, or expensive. Thus, the development of new approaches for the preparation of acyl fluorides is still highly desirable.

Shelf-stable *N*-trifluoromethylthiophthalimide has been developed as an easily synthesized and efficient trifluoromethylthiolation reagent, and an array of valuable compounds were obtained employing this versatile SCF₃-reagent.¹⁴ In 2000, Munavalli and coworkers reported the reaction of SCF₃-phthalimide with enamines, affording the α-trifluoromethylthiolated ketones.^{14a} Our group realized the enantioselective trifluoromethylthiolation of β-ketoester^{14b} and oxindoles,^{14c} Cu-catalyzed cross-coupling of boronic acids and alkynes,^{14d} as

(a) Acyl fluorides as synthons in organic synthesis

(b) The reaction of carboxylic acids and *N*-trifluoromethylthiophthalimide under different conditions

Scheme 1 Acyl fluorides as synthons in organic synthesis and the reaction of *N*-trifluoromethylthiophthalimide and carboxylic acids.

KAUST Catalysis Center (KCC), King Abdullah University of Science and Technology (KAUST), Thuwal, 23955-6900, Saudi Arabia. E-mail: huifeng.yue@kaust.edu.sa, magnus.rueping@kaust.edu.sa

†Electronic supplementary information (ESI) available. See DOI: 10.1039/d1qo01633d

‡These authors contributed equally to this work.



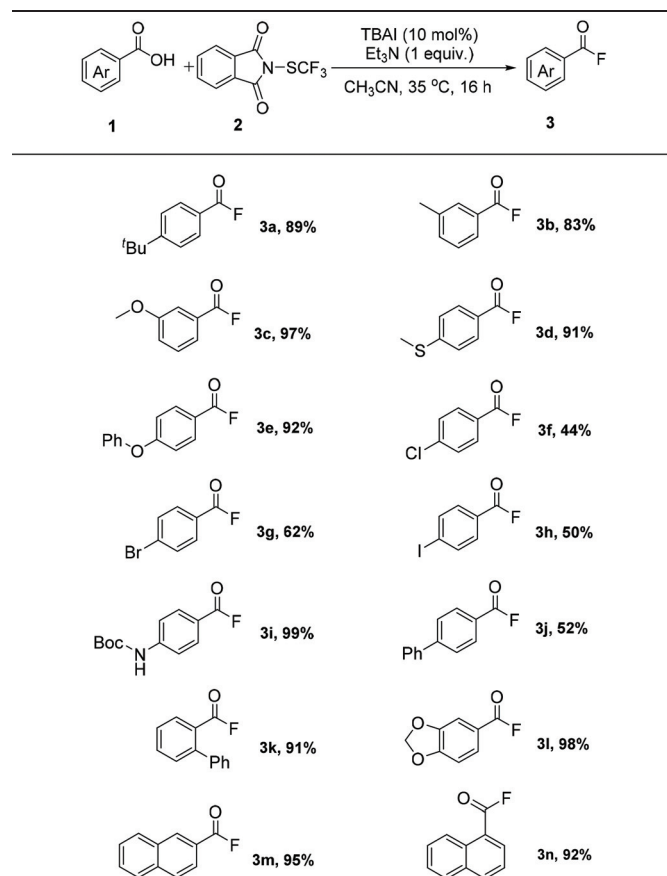
well as the metal-free ring-opening/trifluoromethylthiolation of cycloalkanols¹⁵ with this SCF₃-reagent.

More recently, Hu and coworkers developed a protocol on deoxygenated trifluoromethylthiolation of carboxylic acids in the presence of FeCl₃ and PPh₃, wherein SCF₃-phthalimide acted as a nucleophilic “SCF₃” source.^{14e} In contrast, we herein report that electrophilic *N*-trifluoromethylthiophthalimide acts as a fluorinated reagent in the reaction of carboxylic acids (Scheme 1b).

We started our investigation by evaluating the reaction of 4-(*tert*-butyl)benzoic acid **1a** and *N*-trifluoromethylthiophthalimide **2a** (Table 1). After a series of screening, the optimal reaction conditions were assigned as follows: 10 mol% TBAI as catalyst, 1 equiv. of Et₃N as reductant in 2 mL CH₃CN at 35 °C. The use of DIPEA as base gave lower yield, while the application of other bases including 2,6-lutidine, pyridine, and ⁿBnN led to no formation of the desired product. Other solvents such as DMF, DMA, DMSO, THF, acetone were also suitable for this transformation, albeit delivering the acyl fluoride product in low to moderate yields. Using NaI or KI instead of TBAI decreased the yields dramatically. Reversing the ratio of **1a** and **2** from 1:1 to 1:2 also damaged the yield. Control experiments showed that both TBAI and Et₃N are essential for the high efficiency of this transformation.

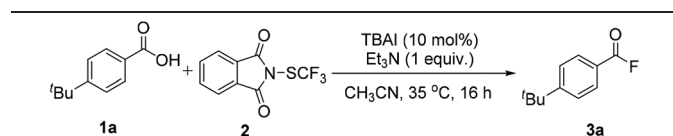
With the optimized reaction conditions in hand, the generality of the fluorination reaction was first examined. As shown in Table 2, a variety of aryl carboxylic acids could undergo this efficient fluorination transformation smoothly, affording the corresponding products in good to excellent yields. In addition to alkyl (**3a** and **3b**), methoxyl (**3c**), methylthio (**3d**), and phe-

Table 2 Substrate scope of the fluorination reaction of aryl carboxylic acids^{a,b}



^a Reaction conditions: Reaction conditions: **1** (0.40 mmol), **2** (0.20 mmol), TBAI (10 mol%), Et₃N (1 equiv.) in CH₃CN (2 mL) at 35 °C for 16 h. ^b Isolated yield.

Table 1 Optimization of the reaction of carboxylic acid and *N*-trifluoromethylthiophthalimide to form acyl fluoride^a



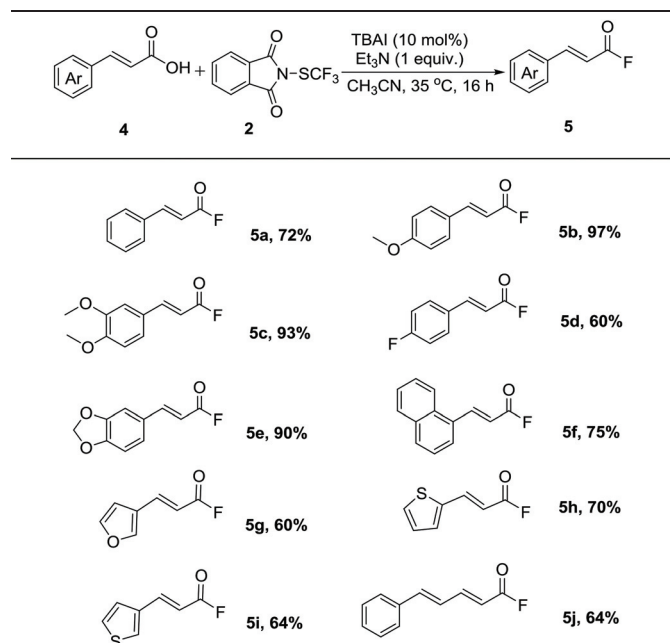
Entry	Variables	Yield ^b (%)
1	None	91
2	DIPEA as base	57
3	2,6-Lutidine as base	0
4	Pyridine as base	0
5	ⁿ BnN as base	0
6	DMF as solvent	55
7	DMA as solvent	60
8	DMSO as solvent	35
9	THF as solvent	42
10	Acetone as solvent	33
11	10 mol% NaI as additive	60
12	10 mol% KI as additive	42
13	0.5 mL CH ₃ CN	46
14	1a : 2 = 1:2	42
15	No TBAI	50
16	No Et ₃ N	0

^a Reaction conditions: **1a** (0.40 mmol), **2** (0.20 mmol), TBAI (10 mol%), Et₃N (1 equiv.) in CH₃CN (2 mL) at 35 °C for 16 h. ^b GC Yields using dodecane as internal standard.

noxy (**3e**) functional groups, reactive chloride (**3f**), bromide (**3g**), iodide (**3h**) were also tolerated in this fluorination protocol, allowing the further sequential functionalization of the generated acyl fluoride products. Aryl carboxylic acid bearing *N*-Boc protected amine was fluorinated in 99% yield (**3i**). Also, biphenyl carboxylic acids could undergo this transformation with good to high efficiency (**3j** and **3k**). In addition, bicyclic carboxylic acid bearing acetal group (**3l**), as well as naphthyl carboxylic acid (**3m** and **3n**), could all give the corresponding product in high yield. Notably, steric hindrance seems to have no significant influence on the reactivity of the substrates (**3b**, **3c**, **3k**, and **3n**).

Gratefully, our fluorination protocol could be readily extended to vinyl carboxylic acids. As shown in Table 3, the reaction of cinnamic acid proceeded in good yield (**5a**). Vinyl carboxylic acids bearing methoxyl (**5b** and **5c**) and fluoride (**5d**) on the aromatic ring underwent the protocol in good to excellent yields. The reactions of vinyl carboxylic acids containing benzodioxole and naphthyl groups (**5e** and **5f**) with *N*-trifluoromethylthiophthalimide took place in good to high yields. Importantly, heterocycles such as furan and thiophene (**5e–5i**) were also tolerated in this protocol, providing the possi-



Table 3 Substrate scope of the fluorination reaction of vinyl carboxylic acids^{a,b}

^a Reaction conditions: Reaction conditions: **4** (0.40 mmol), **2** (0.20 mmol), TBAI (10 mol%), Et₃N (1 equiv.) in CH₃CN (2 mL) at 35 °C for 16 h. ^b Isolated yield.

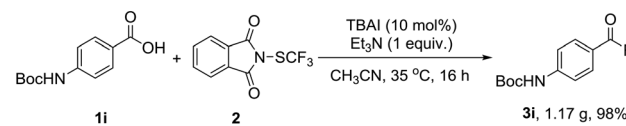
bility for the synthesis of pharmaceutical-related molecules. Moreover, larger π -extended vinyl acid could also be converted to the corresponding acyl fluoride in good yield (**5j**).

In order to demonstrate the practicality of this newly developed fluorination methodology from carboxylic acids, the gram-scale experiment of phenyl naphthalene-2-carboxylate **1i** was conducted, and 98% yield of the desired product **3i** was obtained (Scheme 2a). Furthermore, we also achieved the sequential deoxygenated fluorination/decarbonylative alkylation/C–O bond arylation, showing great advantages of this protocol (Scheme 2b).

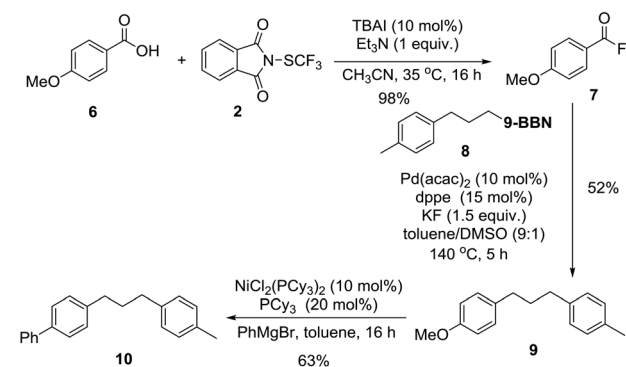
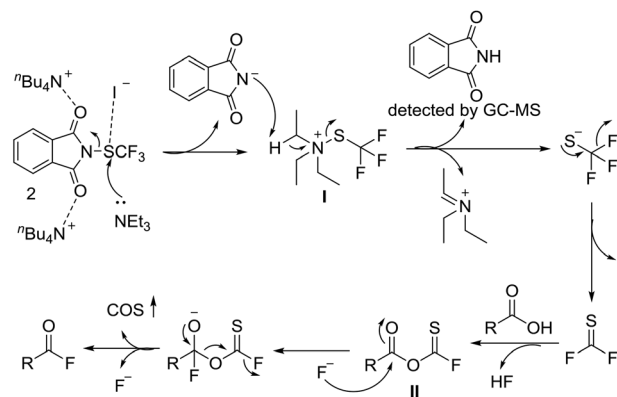
Based on our results and previous studies,^{13,16} a mechanism for this fluorination protocol is proposed (Scheme 3). First, Et₃N attacks the electrophilic sulfur center with the aid of TBAI, affording the phthalimide anion and intermediate **I**. Next, the phthalimide anion attacks one of the protons of the ethyl group at Et₃N to generate the nucleophilic trifluoromethylthio group along with phthalimide and the aminium. Then the [−]SCF₃ anion degrades to CSF₂ with the release of one fluoride ion. The rapid reaction of CSF₂ with carboxylic acid delivers the intermediate **II** that was attacked by a fluoride ion to afford the acyl fluoride product.

In summary, we have developed an efficient deoxygenated fluorination of readily available carboxylic acids. In contrast to previous reports wherein bench-stable *N*-trifluoromethylthiophthalimide was always used as a trifluoromethylthiolation reagent, this newly developed protocol employed it as a fluorinated reagent for the first time. A series of aryl and vinyl car-

a. Gram-scale fluorination reaction



b. Sequential deoxygenative fluorination/decarbonylative alkylation/C–O bond arylation

**Scheme 2** Gram-scale reaction and synthetic application.**Scheme 3** Proposed mechanism for the reaction of carboxylic acids and *N*-trifluoromethylthiophthalimide.

boxylic acid could be converted to acyl fluorides with good to high efficiency. Gram-scale reaction and sequential synthesis, including deoxygenated fluorination/decarbonylative alkylation/C–O bond arylation, were realized in good yield. This protocol provides a good alternative for the fluorination of carboxylic acids.

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

This work was financially supported by the King Abdullah University of Science and Technology (KAUST), Saudi Arabia, Office of Sponsored Research (URF/1/4384).



Notes and references

- (a) P. Kirsch, *Modern Fluoroorganic Chemistry: Synthesis, Reactivity, Applications*, Wiley-VCH, Weinheim, 2004; (b) D. O'Hagan, Understanding organofluorine chemistry. An introduction to the C–F bond, *Chem. Soc. Rev.*, 2008, **37**, 308–319; (c) J. T. Welch, *Fluorine in Medicinal Chemistry and Chemical Biology*, ed. I. Ojima, Wiley-Blackwell, Chichester, 2009; (d) M. C. Belhomme, T. Besset, T. Poisson and X. Pannecoucke, Recent progress toward the introduction of functionalized difluoromethylated building blocks onto C (sp²) and C (sp) centers, *Chem. – Eur. J.*, 2015, **21**, 12836–12865; (e) M. V. Ivanova, A. Bayle, T. Besset, T. Poisson and X. Pannecoucke, Copper-Mediated Formation of Aryl, Heteroaryl, Vinyl and Alkynyl Difluoromethylphosphonates: A General Approach to Fluorinated Phosphate Mimics, *Angew. Chem., Int. Ed.*, 2015, **54**, 13406–13410; (f) K. Grollier, A. De Zordo-Banliat, F. Bourdreux, B. Pegot, G. Dagousset, E. Magnier and T. Billard, (Trifluoromethylselenyl) methylchalcogenyl as Emerging Fluorinated Groups: Synthesis under Photoredox Catalysis and Determination of the Lipophilicity, *Chem. – Eur. J.*, 2021, **27**, 6028–6033; (g) F. Brünig, C. R. Pitts, J. Kalim, D. Bornemann, C. Ghiazza, J. de Montmollin, N. Trapp, T. Billard and A. Togni, Difluoro (aryl) (perfluoroalkyl)- λ 4-sulfanes and Selanes: Missing Links of Trichloroisocyanuric Acid/Potassium Fluoride Chemistry, *Angew. Chem., Int. Ed.*, 2019, **58**, 18937–18941; (h) A. Tlili, E. Ismalaj, Q. Glenadel, C. Ghiazza and T. Billard, Synthetic Approaches to Trifluoromethylselenolated Compounds, *Chem. – Eur. J.*, 2018, **24**, 3659–3670; (i) X. Zhao, H.-Y. Tu, L. Guo, S. Zhu, F.-L. Qing and L. Chu, Intermolecular selective carboacylation of alkenes via nickel-catalyzed reductive radical relay, *Nat. Commun.*, 2018, **9**, 3488; (j) D. Chen, L. Xu, T. Long, S. Zhu, J. Yang and L. Chu, Metal-free, intermolecular carbopyridylation of alkenes via visible-light-induced reductive radical coupling, *Chem. Sci.*, 2018, **9**, 9012–9017.
- (a) Y. Ogiwara and N. Sakai, Acyl Fluorides in Late-Transition-Metal Catalysis, *Angew. Chem., Int. Ed.*, 2020, **59**, 574–594; (b) Y. Zhang and T. Rovis, A unique catalyst effects the rapid room-temperature cross-coupling of organozinc reagents with carboxylic acid fluorides, chlorides, anhydrides, and thioesters, *J. Am. Chem. Soc.*, 2004, **126**, 15964–15965; (c) Y. Ogiwara, Y. Maegawa, D. Sakino and N. Sakai, Palladium-catalyzed coupling of benzoyl halides with aryl-trifluorosilanes leading to diaryl ketones, *Chem. Lett.*, 2016, **45**, 790–792; (d) Y. Ogiwara, D. Sakino, Y. Sakurai and N. Sakai, Acid fluorides as acyl electrophiles in Suzuki–Miyaura coupling, *Eur. J. Org. Chem.*, 2017, 4324–4327; (e) Y. Ogiwara, Y. Iino and N. Sakai, Catalytic C–H/C–F coupling of azoles and acyl fluorides, *Chem. – Eur. J.*, 2019, **25**, 6513–6516; (f) Y. Ogiwara, Y. Sakurai, H. Hattori and N. Sakai, Palladium-catalyzed reductive conversion of acyl fluorides via ligand-controlled decarbonylation, *Org. Lett.*, 2018, **20**, 4204–4208; (g) S. T. Keaveney and F. Schoenebeck, Palladium-Catalyzed Decarbonylative Trifluoromethylation of Acid Fluorides, *Angew. Chem., Int. Ed.*, 2018, **57**, 4073–4077; (h) Y. Okuda, J. Xu, T. Ishida, C.-a. Wang and Y. Nishihara, Nickel-catalyzed decarbonylative alkylation of aryl fluorides assisted by Lewis-acidic organoboranes, *ACS Omega*, 2018, **3**, 13129–13140; (i) C. A. Malapit, J. R. Bour, C. E. Brigham and M. S. Sanford, Base-free nickel-catalysed decarbonylative Suzuki–Miyaura coupling of acid fluorides, *Nature*, 2018, **563**, 100–104; (j) S. Sakurai, T. Yoshida and M. Tobisu, Iridium-catalyzed decarbonylative coupling of acyl fluorides with arenes and heteroarenes via CH activation, *Chem. Lett.*, 2019, **48**, 94–97; (k) Z. Wang, X. Wang and Y. Nishihara, Nickel-catalysed decarbonylative borylation of aryl fluorides, *Chem. Commun.*, 2018, **54**, 13969–13972; (l) J. A. Kalow and A. G. Doyle, Enantioselective ring opening of epoxides by fluoride anion promoted by a cooperative dual-catalyst system, *J. Am. Chem. Soc.*, 2010, **132**, 3268–3269; (m) Y. Liang, A. Taya, Z. Zhao, N. Saito and N. Shibata, Deoxyfluorination of acyl fluorides to trifluoromethyl compounds by FLUOLEAD®/Olah's reagent under solvent-free conditions, *Beilstein J. Org. Chem.*, 2020, **16**, 3052–3058.
- (a) E. Bappert, P. Müller and G. C. Fu, Asymmetric [3 + 2] annulations catalyzed by a planar-chiral derivative of DMAP, *Chem. Commun.*, 2006, 2604–2606; (b) T. Poisson, V. Dalla, C. Papamicael, G. Dupas, F. Marsais and V. Levacher, DMAP-organocatalyzed O-silyl-O-(or C)-benzoyl interconversions by means of benzoyl fluoride, *Synlett*, 2007, 0381–0386; (c) T. Poisson, V. Dalla, F. Marsais, G. Dupas, S. Oudeyer and V. Levacher, Organocatalytic enantioselective protonation of silyl enolates mediated by Cinchona alkaloids and a latent source of HF, *Angew. Chem., Int. Ed.*, 2007, **46**, 7090–7093; (d) S. J. Ryan, L. Candish and D. W. Lupton, N-heterocyclic carbene-catalyzed generation of α , β -unsaturated acyl imidazoliums: synthesis of dihydropyranones by their reaction with enolates, *J. Am. Chem. Soc.*, 2009, **131**, 14176–14177; (e) S. J. Ryan, L. Candish and D. W. Lupton, N-heterocyclic carbene-catalyzed (4 + 2) cycloaddition/decarboxylation of silyl dienol ethers with α , β -unsaturated acid fluorides, *J. Am. Chem. Soc.*, 2011, **133**, 4694–4697.
- (a) G. Olah and S. Kuhn, Organic Fluorine Compounds. XXVII. Preparation of Acyl Fluorides with Anhydrous Hydrogen Fluoride. The General Use of the Method of Colson and Fredenhagen, *J. Org. Chem.*, 1961, **26**, 237–238; (b) C. Tullock and D. Coffman, Synthesis of fluorides by metathesis with sodium fluoride, *J. Org. Chem.*, 1960, **25**, 2016–2019; (c) A. Pittman and D. Sharp, Fluoro Ketone—Metal Fluoride Adducts as Fluorinating Agents in the Preparation of Fluorosilanes and Fluorinated Acyl Fluorides, *J. Org. Chem.*, 1966, **31**, 2316–2318.
- H. X. Song, Z. Y. Tian, J. C. Xiao and C. P. Zhang, Tertiary-Amine-Initiated Synthesis of Acyl Fluorides from Carboxylic Acids and CF₃SO₂OCF₃, *Chem. – Eur. J.*, 2020, **26**, 16261–16265.



- 6 Z. Yang, S. Chen, F. Yang, C. Zhang, Y. Dou, Q. Zhou, Y. Yan and L. Tang, PPh₃/Selectfluor-Mediated Transformation of Carboxylic Acids into Acid Anhydrides and Acyl Fluorides and Its Application in Amide and Ester Synthesis, *Eur. J. Org. Chem.*, 2019, 5998–6002.
- 7 T. Scattolin, K. Deckers and F. Schoenebeck, Direct synthesis of acyl fluorides from carboxylic acids with the bench-stable solid reagent (Me₄N) SCF₃, *Org. Lett.*, 2017, **19**, 5740–5743.
- 8 S. Groß, S. Laabs, A. Scherrmann, A. Sudau, N. Zhang and U. Nubbemeyer, Improved syntheses of cyanuric fluoride and carboxylic acid fluorides, *J. Prakt. Chem.*, 2000, **342**, 711–714.
- 9 C. Chen, C.-T. Chien and C.-H. Su, Preparation of acyl fluorides with hydrogen fluoride-pyridine and 1, 3-dicyclohexylcarbodiimide, *J. Fluorine Chem.*, 2002, **115**, 75–77.
- 10 (a) A. L'Heureux, F. Beaulieu, C. Bennett, D. R. Bill, S. Clayton, F. LaFlamme, M. Mirmehrabi, S. Tadayon, D. Tovell and M. Couturier, Aminodifluorosulfonium salts: selective fluorination reagents with enhanced thermal stability and ease of handling, *J. Org. Chem.*, 2010, **75**, 3401–3411; (b) F. Beaulieu, L.-P. Beauregard, G. Courchesne, M. Couturier, F. LaFlamme and A. L'Heureux, Aminodifluorosulfonium tetrafluoroborate salts as stable and crystalline deoxofluorinating reagents, *Org. Lett.*, 2009, **11**, 5050–5053.
- 11 (a) L. A. Carpino and A. El-Faham, Tetramethylfluoroformamidinium hexafluorophosphate: a rapid-acting peptide coupling reagent for solution and solid phase peptide synthesis, *J. Am. Chem. Soc.*, 1995, **117**, 5401–5402; (b) L. A. Carpino, M. Beyermann, H. Wenschuh and M. Bienert, Peptide synthesis via amino acid halides, *Acc. Chem. Res.*, 1996, **29**, 268–274.
- 12 Y. Liang, Z. Zhao, A. Taya and N. Shibata, Acyl Fluorides from Carboxylic Acids, Aldehydes, or Alcohols under Oxidative Fluorination, *Org. Lett.*, 2021, **23**, 847–852.
- 13 I. Saidalimu, S. Suzuki, E. Tokunaga and N. Shibata, Successive C–C bond cleavage, fluorination, trifluoromethylthio- and pentafluorophenylthiolation under metal-free conditions to provide compounds with dual fluoro-functionalization, *Chem. Sci.*, 2016, **7**, 2106–2110.
- 14 (a) S. Munavalli, D. Rohrbaugh, D. Rossman, F. Berg, G. Wagner and H. Durst, Trifluoromethylsulfenylation of masked carbonyl compounds, *Synth. Commun.*, 2000, **30**, 2847–2854; (b) T. Bootwicha, X. Liu, R. Pluta, I. Atodiresei and M. Rueping, N-Trifluoromethylthiophthalimide: A Stable Electrophilic SCF₃-Reagent and its Application in the Catalytic Asymmetric Trifluoromethylsulfenylation, *Angew. Chem., Int. Ed.*, 2013, **52**, 12856–12859; (c) M. Rueping, X. Liu, T. Bootwicha, R. Pluta and C. Merckens, Catalytic enantioselective trifluoromethylthiolation of oxindoles using shelf-stable N-(trifluoromethylthio) phthalimide and a cinchona alkaloid catalyst, *Chem. Commun.*, 2014, **50**, 2508–2511; (d) R. Pluta, P. Nikolaienko and M. Rueping, Direct catalytic trifluoromethylthiolation of boronic acids and alkynes employing electrophilic shelf-stable N-(trifluoromethylthio) phthalimide, *Angew. Chem., Int. Ed.*, 2014, **53**, 1650–1653; (e) R. Mao, S. Bera, A. Cheseaux and X. Hu, Deoxygenative trifluoromethylthiolation of carboxylic acids, *Chem. Sci.*, 2019, **10**, 9555–9559; (f) W. Xu, J. Ma, X. A. Yuan, J. Dai, J. Xie and C. Zhu, Synergistic catalysis for the umpolung trifluoromethylthiolation of tertiary ethers, *Angew. Chem., Int. Ed.*, 2018, **57**, 10357–10361; (g) Q. Xiao, Q. He, J. Li and J. Wang, 1, 4-Diazabicyclo [2.2. 2] octane-Promoted Aminotrifluoromethylthiolation of α , β -Unsaturated Carbonyl Compounds: N-Trifluoromethylthio-4-nitrophthalimide Acts as Both the Nitrogen and SCF₃ Sources, *Org. Lett.*, 2015, **17**, 6090–6093; (h) S. Mukherjee, T. Patra and F. Glorius, Cooperative catalysis: a strategy to synthesize trifluoromethyl-thioesters from aldehydes, *ACS Catal.*, 2018, **8**, 5842–5846.
- 15 T. Ji, X.-Y. Chen, L. Huang and M. Rueping, Remote Trifluoromethylthiolation Enabled by Organophotocatalytic C–C Bond Cleavage, *Org. Lett.*, 2020, **22**, 2579–2583.
- 16 (a) R. Honeker, J. B. Ernst and F. Glorius, Transition-Metal-Free Trifluoromethylthiolation of N-Heteroarenes, *Chem. – Eur. J.*, 2015, **21**, 8047–8051; (b) H. X. Song, Z. Y. Tian, J. C. Xiao and C. P. Zhang, Tertiary-Amine-Initiated Synthesis of Acyl Fluorides from Carboxylic Acids and CF₃SO₂OCCF₃, *Chem. – Eur. J.*, 2020, **26**, 16261–16265.

