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Stereoselective [3+2] Cycloaddition of *N-tert*-Butanesulfinyl Imines to Arynes Facilitated by Removable $PhSO_2CF_2$ Group: Synthesis and Transformation of Cyclic Sulfoximines†

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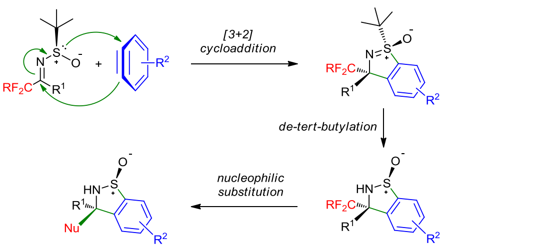
An unprecedented [3+2] cycloaddition between *N-tert*-butanesulfinyl imines and arynes provides a stereoselective method for the synthesis of cyclic sulfoximines. Not only does the difluoro(phenylsulfonyl)methyl group play an important role in facilitating the cycloaddition reaction, it can also be removed or substituted through the transformation of the difluorinated cyclic sulfoximines to cyclic sulfinamides.

Since their initial discovery in the late 1940s, sulfoximines have played prominent roles in modern chemistry.[1] Due to their unique structure and biological activity, sulfoximines have been widely applied in asymmetric synthesis (both as chiral auxiliaries and ligands) and in medicinal chemistry and crop protection.[2-4] A sulfoximine functionality is generally constructed by three known methods: a) oxidative imination of a sulfoxide, b) oxidation of a sulfilimine, and c) substitution reaction with a sulfonimidoyl halide or a sulfonimidate.[1] Enantioenriched sulfoximines are commonly obtained by resolution of racemic mixtures,[5] or oxidative imination of enantioenriched sulfoxides.[1,2,6] Although enantioenriched cyclic sulfoximines can be obtained from multi-step elaborations of enantioenriched linear ones,[7] there is still lack of one-step methods for their synthesis.

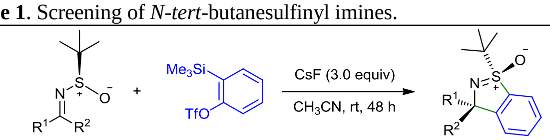
Enantiomerically pure *N-tert*-butanesulfinyl (TBS) imines, which were first reported by García Ruano and co-workers in 1996,[8] have found wide applications in asymmetric synthesis since Ellman's seminal work on the practical preparation of enantiomerically pure *N-tert*-butanesulfinamide and its subsequent condensation with aldehydes and ketones.[9,10a] However, the synthetic application of *N*-TBS imines has mainly been based on the high electrophilicity of C=N bonds towards many different nucleophiles, which affords a variety of structurally diverse enantioenriched amines.[10] To the best of our knowledge, however, the use of *N*-TBS imine as a quasi-1,3-dipole[11,12] for cycloaddition reactions has never been reported.[13] Herein, we report an unprecedented stereoselective [3+2] cycloaddition of enantiopure difluorinated *N*-TBS imines with arynes[14] for the synthesis of enantiopure cyclic sulfoximines (1-(*tert*-butyl)benzo[d]iso-thiazole 1-oxides) and their subsequent transformation into various cyclic sulfinamides (Scheme 1).

At the onset of our investigation, *o*-trimethylsilyl phenyl triflate (**3a**) was chosen as a model substrate,[15] and an excess amount of CsF was used as an activator to generate the benzyne



Scheme 1. [3 + 2] Cycloaddition of *N-tert*-butanesulfinyl imines to arynes and subsequent transformations.

Table 1. Screening of *N-tert*-butanesulfinyl imines.



1 or **2a** (1.0 equiv) **3a** (2.0 equiv) **4** or **5a**

Entry	Sulfinimine	R^1	R^2	Sulfoximine	Yield[a] (%)	dr[b]	er[c]
1	**1a**	Ph	H	**4a**	0[d]	-	-
2	**1b**	Ph	Me	**4b**	0[d]	-	-
3	**1c**	Ph	Ph	**4c**	0[d]	-	-
4	**1d**	Ph	CF_2H	**4d**	32	>99:1[e]	>99:1
5	**1e**	CF_3	Ph	**4e**	0[f]	-	-
6	**1f**	Ph	CH_2F	**5f**	0[d]	-	-
7	**2a**	CF_2SO_2Ph	Ph	**5a**	74	>99:1	>99:1
8	**2a**	CF_2SO_2Ph	Ph	**5a**	87[g]	>99:1	>99:1

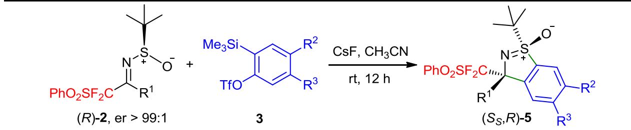
[a] Isolated yield. [b] Determined by ^{19}F NMR analysis of the crude product. [c] Determined by chiral HPLC analysis of the isolated product. [d] Imines **1a-c** and **1f** were recovered. [e] Determined by HPLC-MS analysis of the crude product. [f] Imine **1e** decomposed. [g] Conditions: **2a**/**3a**/CsF = 1:3:5, CH_3CN, rt, 12 h.

intermediate (see Table 1);[16] the reactions between *N*-TBS imines **1a-c** and **3a** were carried out at room temperature for 48 h using acetonitrile as a solvent with the reactant ratio **1**:**3a**:CsF = 1:2:3 (Table 1, entries 1-3). However, sulfinimines **1a-c** were recovered almost quantitatively. Inspired by the excellent modulating ability of neighbouring fluorine substitution upon the reactivity of organic compounds,[17] we envisioned that the introduction of fluorine atom(s) at the α-position of the C=N functionality of *N*-TBS imines might be able to significantly tune their reactivity by enhancing the electrophilicity of the imino carbon atom, while keeping the sulfur atom (of sulfinyl group) with reasonable nucleophilicity, thus promoting the desired [3+2] cycloaddition. Preliminary results showed that the reaction with **1d** could afford [3+2] cycloaddition product **4d** in 32% yield with excellent stereoselectivity (dr > 99:1, er > 99:1) (Table 1, entry 4).[18,19] Although **1e** is expected to be more reactive than **1d,** its reaction with **3a** failed to give the desired product; indeed, a complete decomposition of **1e** was detected (Table 1, entry 5). The poor yields (when **1d** and **1e** were used in the reaction with benzyne) can be partially attributed to their sensitivity to humidity.[20] Moreover, similar to non-fluorinated sulfinimines **1a-c**, monofluorinated sulfinimine **1f** was found to be inert under the same reaction conditions with **1f** being recovered (Table 1, entry 6). All these results indicated that α,α-difluoro substitution on *N*-TBS imines plays a crucial role in tuning their chemical reactivity as quasi-1,3-dipoles.

To find more reactive sulfinimine-type 1,3-dipoles, an exhaustive screening of the difluorinated sulfinimines was carried out. It was found that $PhSO_2CF_2$-sulfinimines **2** are generally air- and moisture-stable and can be readily prepared from *tert*-butanesulfinamide and the corresponding ketones. The [3+2] cycloaddition between **2a** and benzyne was efficient, and sulfoximine **5a** was obtained in 74% yield (Table 1, entry 7). The excellent reactivity of **2a** toward benzyne can be attributed to both the strong electron-withdrawing ability of the $PhSO_2CF_2$ group and the steric protection of C=N by the relatively hydrophobic $PhSO_2$ group. After further optimization of the reaction between sulfinimine **2a** and benzyne precursor **3a**, the optimal yield of **5a** (87%) was obtained when the reaction was performed at room temperature for 12 h with the reactant ratio **2a**:**3a**:CsF = 1:3:5 (Table 1, entry 8). It is noteworthy that, although the reactant ratio, temperature, and reaction time can somewhat influence the yields of **5a**, these parameters have no influence on the stereochemical outcome of this reaction (see ESI† section 2). The absolute configuration of *N*-TBS imine **2a** was determined by the X-ray crystal structure of its para-brominated analogue **2e**, and that of product **5a** was determined by its X-ray crystal structure analysis (see ESI† section 3.1).[19] It turned out that the reaction between **2a** and **3a** proceeded in a highly stereoselective mode, giving product **5a** (dr > 99:1, er > 99:1) with the configuration of the sulfur stereogenic center retained.

By using the optimized reaction conditions as standard (see Table 1, entry 8), we examined the substrate scope of this novel [3+2] cycloaddition reaction with enantiopure $PhSO_2CF_2$-sulfinimines. As shown in Table 2, a variety of aromatic *N*-TBS imines **2a-i**, bearing either electron-donating or electron-withdrawing substituents, could undergo the reaction smoothly to provide **5a-i** in good yields with excellent stereocontrol (dr > 99:1) (Table 2, entries 1-9). When styryl sulfinimine **2j** was employed, the reaction proceeded readily giving **5j** as the single product in 61% yield with excellent diastereomeric control (dr > 99:1) (Table 2, entry 10). Moreover, alkyl sulfinimine **2k** also underwent the reaction, giving **5k** in lower yield (36%) but still with excellent diastereomeric ratio (dr > 99:1) (Table 2, entry 11). To underline the practicality and efficiency of this novel stereoselective [3+2] cycloaddition reaction, several other aryne precursors **3b-e** were used to react with *N*-TBS imines **2**. When the standard reaction conditions (except that the temperature was elevated to 80 °C) were applied, **3b-e** readily reacted with **2a-b**, **2d**, and **2f** to give desired cycloaddition products **5l-u** in satisfactory yields (60-91%) with excellent stereocontrol (dr > 99:1) (Table 2, entries 12-21). When aryne precursor **3e** was employed to react with **2a** under similar reaction conditions, a mixture of two regio-isomers of **5u** was obtained in a ratio of 46:54 (Table 2, entry 21), supporting the involvement of an aryne intermediate in this reaction.

Table 2. [3+2] Cycloaddition of $PhSO_2CF_2$-sulfinimines with arynes.[a]

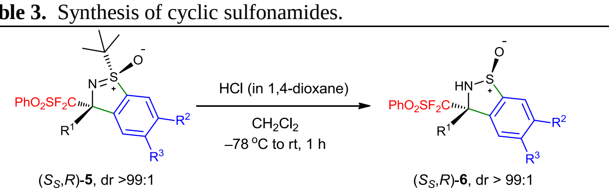


R^2, R^3 = H (**3a**); R^2, R^3 = Me (**3b**); R^2 + R^3 = $-(CH_2)_3-$ (**3c**);
R^2, R^3 = MeO (**3d**); R^2 = Me, R^3 = H (**3e**).

Entry	Sulfinimine	3	Sulfoximine	Yield[b] (%)	dr[c]
1	**2a** R^1 = Ph	**3a**	**5a**	87	>99:1
2	**2b** R^1 = 3-MeC_6H_4	**3a**	**5b**	81	>99:1
3	**2c** R^1 = 4-MeC_6H_4	**3a**	**5c**	62	>99:1
4	**2d** R^1 = 4-ClC_6H_4	**3a**	**5d**	73	>99:1
5	**2e** R^1 = 4-BrC_6H_4	**3a**	**5e**	78	>99:1
6	**2f** R^1 = 3-$MeOC_6H_4$	**3a**	**5f**	76	>99:1
7	**2g** R^1 = 4-$MeOC_6H_4$	**3a**	**5g**	80	>99:1
8	**2h** R^1 = 4-$CF_3C_6H_4$	**3a**	**5h**	78	>99:1
9	**2i** R^1 = 6-Br-2-Naph	**3a**	**5i**	90	>99:1
10	**2j** R^1 = (*E*)-styryl	**3a**	**5j**	61	>99:1
11	**2k** R^1 = *i*Pr	**3a**	**5k**	36	>99:1
12	**2a** R^1 = Ph	**3b**	**5l**	80	>99:1
13[d]	**2b** R^1 = 3-MeC_6H_4	**3b**	**5m**	74	>99:1
14[d]	**2d** R^1 = 4-ClC_6H_4	**3b**	**5n**	70	>99:1
15[d]	**2f** R^1 = 3-$MeOC_6H_4$	**3b**	**5o**	78	>99:1
16	**2a** R^1 = Ph	**3c**	**5p**	75	>99:1
17[d]	**2b** R^1 = 3-MeC_6H_4	**3c**	**5q**	72	>99:1
18[d]	**2f** R^1 = 3-$MeOC_6H_4$	**3c**	**5r**	74	>99:1
19[d]	**2a** R^1 = Ph	**3d**	**5s**	62	>99:1
20[d]	**2f** R^1 = 3-$MeOC_6H_4$	**3d**	**5t**	60	>99:1
21	**2a** R^1 = Ph	**3e**	**5u**	91 (46:54)[e]	>99:1/ >99:1

[a] Reactant ratio: **2**: **3**: CsF = 1:3:5. [b] Isolated yield. [c] The dr of **5** was determined by ^{19}F NMR analysis of the crude product. [d] Performed at 80 °C. [e] The product **5u** was obtained as a mixture of two regio-isomers.

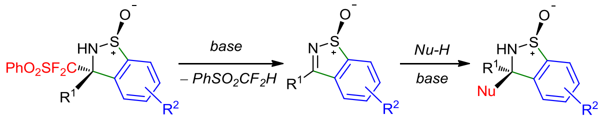
Table 3. Synthesis of cyclic sulfonamides.



Entry	Sulfoximine	R^1	R^2	R^3	Sulfinamide[a]	Yield[b] (%)
1	**5a**	Ph	H	H	**6a**	96
2	**5b**	3-MeC_6H_4	H	H	**6b**	92
3	**5e**	4-BrC_6H_4	H	H	**6c**	93
4	**5h**	4-$CF_3C_6H_4$	H	H	**6d**	94
5	**5i**	6-Br-2-Naph	H	H	**6e**	94
6	**5j**	(*E*)-styryl	H	H	**6f**	96
7	**5k**	*i*Pr	H	H	**6g**	91
8	**5l**	Ph	Me	Me	**6h**	92
9	**5m**	3-MeC_6H_4	Me	Me	**6i**	96
10	**5p**	Ph	$(CH_2)_3$		**6j**	95

[a] The dr of **6** was determined by ^{19}F NMR analysis of the crude product. [b] Isolated yield.

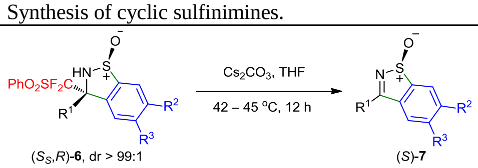
With cyclic sulfoximes **5** in hand, we investigated their transformation into cyclic sulfinamides **6** by de-*tert*-butylation. Although chiral cyclic sulfonamides (sultams) have become an important class of synthetic targets,[21] there are only very few examples available for the stereocontrolled synthesis of cyclic sulfinamides.[22] After a brief scanning of different reaction conditions, we found that alkyl, alkenyl and aryl-substituted cyclic sulfoximines **5** could be readily converted into cyclic sulfinamides **6** in excellent yields with very high stereochemical fidelity (dr > 99:1) upon the treatment of HCl/1,4-dioxane in CH_2Cl_2 at –78 °C (Table 3).[23] The absolute configuration of **6a** was determined by the X-ray crystal structure of its *N*-(6-bromonaphthalen-2-yl)methyl derivative compound **S3** (see ESI† section 3.3),[19] which demonstrates that the configuration of the sulfur stereogenic center was retained during the loss of the *tert*-butyl group.



Scheme 2. Elimination-addition reaction of $PhSO_2CF_2$-substituted sulfonamides.

Subsequently, taking advantage of this nucleofugality of the $PhSO_2CF_2$ anion,[24] we focused on the formation of chiral cyclic sulfinimines from **6** and their subsequent addition reactions with other nucleophiles (Scheme 2). Such an elimination-addition process would be synthetically valuable, as it corresponds to a formal nucleophilic substitution of the $PhSO_2CF_2$ group. After screening of the reaction conditions, it was established that treatment of **6a** with Cs_2CO_3 in THF at 42-45 °C afforded sulfinimine **7a** in 70% yield with 98:2 er (Table 4, entry 1). Other sulfinamides **6b-d**, **6 h** and **6i** could also be treated under the same conditions to give **7b-f** in good yields with high enantioselectivity (Table 4, entries 2-6). The retention of the absolute configuration of the sulfur atom was confirmed by X-ray crystallographic analysis of **7c** (see ESI† section 3.4).[19] Note that these chiral sulfinimines represent a new class of synthons that are otherwise difficult to prepare when employing classical condensation methods.[25] The further reaction of the cyclic

Table 4. Synthesis of cyclic sulfinimines.

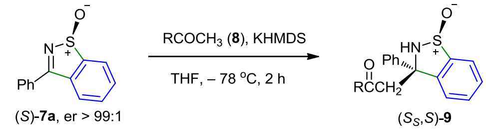


Entry	Sulfinamide	R^1	R^2	R^3	Sulfinimine	Yield[a] (%)	er[b]
1	**6a**	Ph	H	H	**7a**	70	98:2[c]
2	**6b**	3-MeC_6H_4	H	H	**7b**	66	96:4
3	**6c**	4-BrC_6H_4	H	H	**7c**	71	97:3
4	**6d**	4-$CF_3C_6H_4$	H	H	**7d**	73	95:5
5	**6h**	Ph	Me	Me	**7e**	65	93:7
6	**6i**	3-MeC_6H_4	Me	Me	**7f**	62	95:5

[a] Isolated yield. [b] Determined by chiral HPLC analysis of **7**. [c] The er of **7a** can be improved to > 99:1 after a single recrystallization.

sulfinimines was exemplified by the addition of several enolate anions to enantioenriched **7a** (Table 5). When potassium hexamethyldisilazide (KHMDS) was used as a base, the reactions with carbonyl compounds **8** proceeded smoothly at –78 °C to give adducts **9a-f** in excellent yields with high diastereoselectivity (Table 5, entries 1-7). The absolute configuration of the quaternary carbon center of **9c** was identified to be *S* by X-ray crystallographic analysis of its corresponding sulfonamide **S4** (see ESI† section 3.6),[19] which could be rationalized by coordination of the potassium enolate to the sulfinyl oxygen and subsequent addition to the re-face of sulfinimine (*S*)-**7a**.

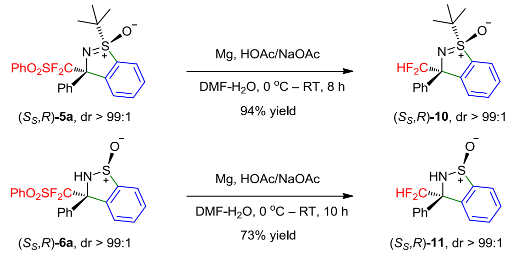
Table 5. Nucleophilic addition to cyclic sulfinimines.[a]



Entry	R	Sulfinamide	Yield[b] (%)	dr[c]	er[c]
1	4-EtC_6H_4	**9a**	93	95:5	99:1
2	4-$NO_2C_6H_4$	**9b**	84	88:12	99:1
3	4-BrC_6H_4	**9c**	95	92:8	99:1
4	2-benzo[*b*]thienyl	**9d**	97	94:6	99:1
5	2-Naph	**9e**	91	95:5	99:1
6	EtO	**9f**	88	95:5	99:1

[a] Reactant ratio: **7a**: **8**: KHMDS = 1:2:2. [b] Total isolated yield of **9**. [c] Determined by chiral HPLC analysis of **9**.

We finally turned our attention to the release of the masked CF_2H from $PhSO_2CF_2$. Upon treatment with Mg^0 under mild acidic conditions (HOAc/AcONa) in DMF-H_2O system,[26] **5a** and **6a** could be conveniently converted into the difluoromethylated products **10** and **11** in high yields with excellent stereochemical fidelity (Scheme 3). Since the CF_2H group can act as a more lipophilic hydrogen bond donor than typical donors such as OH and SH, the CF_2H-containing chiral cyclic sulfoximines and sulfinamides represent interesting new structural motifs for life sciences-related applications.



Scheme 3. Reductive desulfonylation.

In summary, we have shown that difluorinated *N*-TBS imines can act as novel chiral quasi-1,3-dipoles in stereoselective [3+2] cycloaddition reactions with arynes, which opens up a new avenue for the synthesis of enantiopure cyclic sulfoximines. The $PhSO_2CF_2$ group enhances the reactivity of the *N*-TBS imines (due to its electron-withdrawing ability) and improves the stability of such imines against water (by increasing the hydrophobicity), thus facilitating the subsequent stereoselective[3+2] cycloaddition reaction. On the other hand, the synthetic utility of these [3+2] reaction products was conveniently demonstrated by their ready transformation into cyclic sulfinamides via stereoselective de-*tert*-butylation, as well as the subsequent transformation of the cyclic sulfinamides into non-fluorinated ones by a formal nucleophilic substitution of the $PhSO_2CF_2$ group.

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Notes and references

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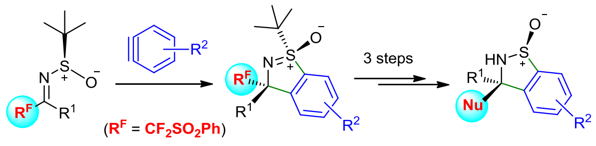
1 M. Reggelin and C. Zur, *Synthesis*, 2000, 1.
2 For reviews, see: (a) H. Okamura and C. Bolm, *Chem. Lett.*, 2004, **33,** 482; (b) H.-J. Gais, *Heteroatom Chem.*, 2007, **18**, 472; (c) C. Worch, A. C. Mayer and C. Bolm, In *Organosulfur Chemistry in Asymmetric Synthesis*, T. Toru and C. Bolm (Eds.), Wiley-VCH: Weinheim, 2008.
3 For recent examples, see: (a) M. Frings, I. Thomé and C. Bolm, *Beilstein J. Org. Chem.*, 2012, **8**, 1443; (b) X. Shen, W. Zhang, L. Zhang, T. Luo, X. Wan, Y. Gu and J. Hu, *Angew. Chem., Int. Ed*., 2012, **51**, 6966; (c) X. Shen, W. Zhang, C. Ni, Y. Gu and J. Hu, *J. Am. Chem. Soc.*, 2012, **134**, 16999.
4 For more recent reviews, see: (a) U. Lücking, *Angew. Chem., Int. Ed.*, 2013, **52**, 9399; (b) V. Bizet, R. Kowalczyk and C. Bolm, *Chem. Soc. Rev.*, 2014, **43**, 2426; (c) X. Shen and J. Hu, *Eur. J. Org. Chem.*, **2014**, doi: 10.1002/ejoc.201402086.
5 (a) C. R. Johnson and C. W. Schroeck, *J. Am. Chem. Soc*., 1973, **95**, 7418; (b) J. Brandt and H. J. Gais, *Tetrahedron: Asymmetry*, 1997, **8**, 909.
6 (a) O. Mancheno and C. Bolm, *Chem. Eur. J*., 2007, **13**, 6674; and references therein; (b) for oxidation of enantioenriched sulfilimines, see: J. Wang, M. Frings and C. Bolm, *Angew. Chem., Int. Ed.*, 2013, **52**, 8661; and references therein.
7 For examples, see: (a) M. Harmata and P. Zheng, *Org. Lett.*, 2007, **9**, 5251; (b) M. Harmata, Y. Chen and C. L. Barnes, *Org. Lett.*, 2007, **9**, 4701; (c) C. Bolm and H. Villar, *Synthesis*, 2005, 1421; and references therein; (d) T. R. Williams and D. J. Cram, *J. Org. Chem.*, 1973, **38**, 20.
8 J. L. Carcá Ruano, I. Fernandez, M. del Prado Catalina and A. A. Cruz, *Tetrahedron: Asymmetry*, 1996, **7**, 3407.
9 G. Liu, D. A. Cogan and J. A. Ellman, *J. Am. Chem. Soc.*, 1997, **119**, 9913.
10 For recent reviews, see: (a) M. T. Robak, M. A. Herbage and J. A. Ellman, *Chem. Rev.*, 2010, **110**, 3600; (b) F. Ferreira, C. Botuha, F. Chemla and A. Pérez-Luna, *Chem. Soc. Rev.*, 2009, **38**, 1162; (c) J. Liu and J. Hu, *Future Med. Chem.*, 2009, **1**, 875.
11 The 1,3-dipoles are generally defined as "having a π-electron system consisting of two filled and one empty orbital and are analogous with the allyl or propargyl anion". According to this criterion, *N*-*tert*-butanesulfinyl imines do not belong to real 1,3-dipoles. See: (a) F. A. Carey and R. J. Sundberg, *Advanced Organic Chemistry*, *Part A: Structure and Mechanisms*, Springer: New York, 2007, pp 873; (b) *1,3-Dipolar Cycloaddition Chemistry*, vol. 1 & 2, A. Padwa (Ed.), Wiley: New York, 1984.
12 For examples of *quasi*-1,3-dipoles, see: (a) E. Brunn and R. Huisgen, *Angew. Chem., Int. Ed. Engl.*, 1969, **8**, 513; (b) R. Huisgen, E. Brunn, R. Gilardi and I. Karle, *J. Am. Chem. Soc.*, 1969, **91**, 7766.
13 There are only two examples on the one-step cyclizations with the C=N-S subunit of sulfinimines forming cyclic sulfinamides. See: (a) F. A. Davis, J. Qu, V. Srirajan, R. Joseph and D. D. Titus, *Heterocycles*, 2002, **58**, 251; (b) T. Andreassen, M. Lorentzen, L.-K. Hansen and O. R. Gautun, *Tetrahedron*, 2009, **65**, 2806.
14 For selected reviews, see: (a) H. Pellisier and M. Santelli, *Tetrahedron*, 2003, **59**, 701; (b) D. Peña, D. Pérez and E. Guitián, *Heterocycles*, 2007, **74**, 89; (c) A. Bhunia, S. R. Yetra and A. T. Biju, *Chem. Soc. Rev.*, 2012, **41**, 3140; (d) P. M. Tadross and B. M. Stoltz, *Chem. Rev.*, 2012, **112**, 3550; (e) C. M. Gampe and E. M. Carreira, *Angew. Chem., Int. Ed.*, 2012, 51, 3766; (f) A. V. Dubrovskiy, N. A. Markina and R. C. Larock, *Org. Biomol. Chem.*, 2013, **11**, 191.
15 Y. Himeshima, T. Sonoda and H. Kobayashi, *Chem. Lett.*, 1983, 1211.
16 (a) C. Ni, L. Zhang and J. Hu, *J. Org. Chem.*, 2008, **73**, 5699; (b) Y. Zeng, L. Zhang, Y. Zhao, C. Ni, J. Zhao and J. Hu, *J. Am. Chem. Soc.*, 2013, **135**, 2955.
17 (a) K. Uneyama, *Organofluorine Chemistry*, Blackwell: Oxford, 2006, pp 101; for recent examples, see: (b) J. M. Baskin, J. A. Prescher, S. T. Laughlin, N. J. Agard, P. V. Chang, I. A. Miller, A. Lo, J. A. Codelli and C. R. Bertozzi, *Proc. Nat. Acad. Sci.*, 2007, **104**, 16793; (c) X. Shen, L. Zhang, Y. Zhao, L. Zhu, G. Li and J. Hu, *Angew. Chem., Int. Ed.*, 2011, **50**, 2588.
18 The absolute configuration of **1d** was determined by the X-ray crystal structure of its analogue **S2**, and that of **5a** was determined by its X-ray crystal structure analysis (see ESI† section 3.1).[19]
19 CCDC 1009678 (**2e**), CCDC 1009680 (**5a**), CCDC 1009679 (**4d**), CCDC 1009681 (**7c**), CCDC 1009682 (**S2**), CCDC 1009683 (**S3**) and CCDC 1009684 (**S4**) contain the supplementary crystallographic data for this paper and its Supporting Information.
20 For discussion on their instability towards moisture, see: (a) H. Wang, X. Zhao, Y. Li and L. Lu, *Org. Lett.*, 2006, **8**, 1379; (b) H. Chen, W. Yu, X. H. Guo, W. D. Meng and Y. G. Huang, *Chin. Chem. Lett.*, 2012, **23**, 277.
21 For recent examples, see: (a) T. Nishimura, A. Noishiki, G. C. Tsui and T. Hayashi, *J. Am. Chem. Soc.*, 2012, **134**, 5056; (b) H. Wang, T. Jiang and M.-H. Xu, *J. Am. Chem. Soc.*, 2013, **135**, 971; (c) G. Yang and W. Zhang, *Angew. Chem., Int. Ed.*, 2013, **52**, 7540; (d) F. Foschi, A. Tagliabue, V. Mihali, T. Pilati, I. Pecnikaj and M. Penso, *Org. Lett.*, 2013, **15**, 3686.
22 (a) M. Wills, R. J. Butlin, I. D. Linney and R. W. Gibson, *J. Chem. Soc., Perkin Trans. 1*, 1991, 3383; (b) M. M. Endeshaw, A. Bayer, L. K. Hansen and O. R. Gautun, *Eur. J. Org. Chem.*, 2006, 5249; (c) M. Harmata and P. Zheng, *Org. Lett.*, 2007, **9**, 5251; (d) J. Coulomb, V.Certal, M.-H. Larraufie, C. Ollivier, J.-P. Corbet, G. Mignani, L. Fensterbank, E. Lacôte and M. Malacria, *Chem. Eur. J.*, 2009, **15**, 10225.
23 For the removal of *S-t*-Bu group in acyclic sulfoximines, see: S. Gaillard, C. Papamicaël, G. Dupas, F. Marsais and V. Levacher, *Tetrahedron*, 2005, **61**, 8138.
24 X. Shen, C. Ni and J. Hu, *Helv. Chim. Acta*, 2012, **95**, 2043.
25 M. Daniel and R. A. Stockman, *Tetrahedron*, 2006, **62**, 8869.
26 C. Ni and J. Hu, *Tetrahedron Lett.*, 2005, **46**, 8273.

TOC



An unprecedented [3+2] cycloaddition between N-tert-butanesulfinyl imines and arynes provides a stereoselective method for the synthesis of cyclic sulfoximines.