DOI: 10.1002/ejoc.201403450

Regio- and Stereoselective Synthesis of Vicinal (*Z*)-Dihaloalkenylsilanes from Silyl Ethynylarenes

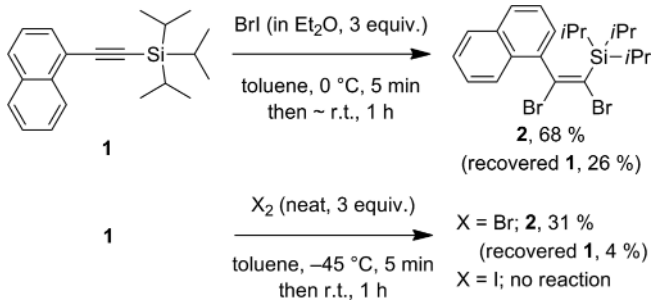
Yuta Yauchi,[a] Masataka Ide,[a] Ryo Shiogai,[a] Takuya Chikugo,[a] and Tetsuo Iwasawa*[a]

Keywords: Alkenes / Stereoselectivity / Vinyl halides / Halogens / Silanes

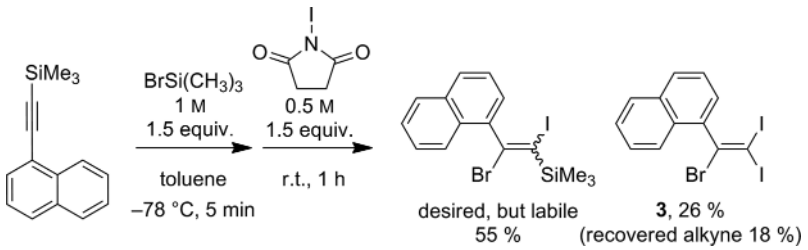
The direct access to (*Z*)-(1-bromo-2-chloro-2-arylvinyl)triisopropylsilane through formal addition of BrCl to triisopropylsilyl ethynylarene was explored. BrCl was generated in situ from commercially available TMSCl and *N*-bromosuccinimide. This simple protocol enabled highly efficient regio- and stereoselective bromochlorination, bis-bromination, and bis-chlorination of the triple bond on a gram scale in the *syn* mode. It thus provided a potentially diverse scaffold for adaptable preparation of differently all-carbon tetrasubstituted olefins.

Introduction

Vinyl substructures are one of the most fundamental moieties in organic synthesis. Specifically, vinyl halides and vinylsilanes are important building blocks, because of their ability to serve as building blocks in a wide variety of functional-group transformations.[1,2] Halogens and silanes can be converted into functional groups by halogen–metal exchange and are significant for carbon–carbon bond-forming reactions by way of transition-metal-catalyzed cross-coupling reactions.[3–5] From a synthetic point of view, multisubstituted vinyls with halogens and silanes are versatile variants of vinyl components.[6,7] Despite the potential utility of such multitunable vinyls, their synthetic availability remains a challenge owing to the inherent difficulty in regio- and stereoselective bis-halogenation (Scheme 1).[8,9] For example, the stoichiometric addition of BrI to alkynylsilane **1**[10] is one way to prepare a multitunable vinyl; however, desired iodobromination does not occur and bis-brominated adduct **2** is given in 68% yield along with 26% of unreacted **1**.[11] Employment of bromine or iodine was ineffective; 31% yield was obtained or the reaction did not proceed. These halogens are commercially available; however, they are occasionally unpleasant to work with. In particular, bromine monochloride (BrCl) is typically



Scheme 1. Reaction of **1** with BrI, Br_2, and I_2.



Scheme 2. Desilylation along with iodobromination of the alkynylsilane.

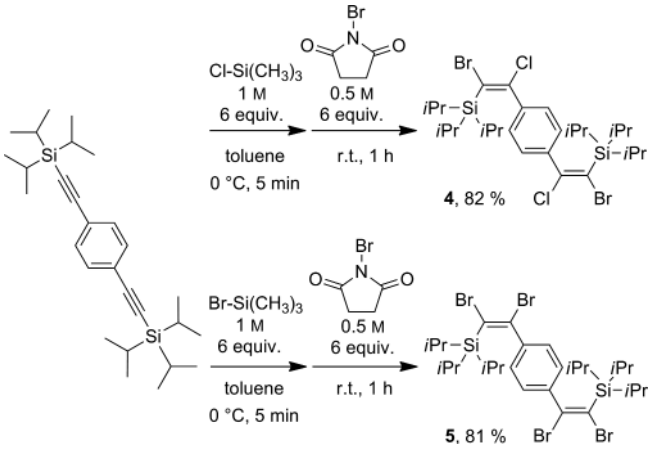
gaseous (b.p. 5 °C) and hygroscopic, which is apt to cause trouble to synthetic chemists in the handling of the reactions,[12] purification of products,[13] and safety.[14] In addition, the most conventional trialkylsilyl moiety, that is, the trimethylsilyl (TMS) group, is delicate under halogenation conditions; for example, desilylation accompanies the

[a] Department of Materials Chemistry, Faculty of Science and Technology, Ryukoku University,
Seta, Otsu 520-2194, Japan
E-mail: iwasawa@rins.ryukoku.ac.jp
http://www.chem.ryukoku.ac.jp/iwasawa/index.html

Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/ejoc.201403450.

addition reaction of BrI (both in situ and neat) to the triple bond of trimethylsilylalkynes and provides **3** in 26% yield (Scheme 2).[15,16]

Herein, we report regio- and stereoselective bis-halogenations of triisopropylsilyl (TIPS) ethynylarenes (Scheme 3) by employing TMSX (X = Cl, Br) and *N*-bromosuccinimide (NBS); the paring TMSX (X = Cl, Br) and NBS induced X and Br to add to the triple bond in a *syn* mode. The high-yielding transformations formed olefins **4** and **5** as single isomers. In addition, the reaction system has significance to generate in situ BrCl formally, because toxic BrCl is difficult to handle in bench-scale experiments owing to its low boiling point of 5 °C. Thus, the methods achieved the selective bis-halogenation of silyl ethynylarenes and provide simple entry to vicinal (*Z*)-dihaloalkenylsilanes.



Scheme 3. *syn*-Selective bis-halogenation to give **4** and **5**.

Results and Discussion

We started the investigation with the reactions of 1,4-bis[(triisopropylsilyl)ethynyl]benzene, as shown in Scheme 3: two combinations, that is, TMSCl/NBS and TMSBr/NBS, were used.[17] In each, a mixture of the starting alkyne and TMSX (1 M) in dichloromethane was stirred at 0 °C, then NBS (0.5 M) in acetonitrile was added, and the reaction was conducted at room temperature.[9,18] For completion of the reactions, 6 equiv. of each TMSX and NBS was needed. Fortunately, analysis of the crude mixture by both ^{1}H NMR and ^{13}C NMR spectroscopy revealed just a single isomer of **4** and **5**. The molecular structures of **4** and **5** were determined by crystallographic analyses (Figure 1), which disclosed their (*Z*) stereochemistry.[19,20]

As summarized in Table 1, screening of different patterns of TMSX/NX′S (X, X′ = I, Br, Cl) were tested. For entry 1, nothing happened upon adding TMSI and NIS; on the other hand, for entry 2, employment of TMSI and NBS did not afford the desired BrI adduct but strangely gave bis-brominated compound **2** in 78% yield. For entry 3, our desired Cl–I adduct was observed, as judged by NMR spectroscopy; however, unfortunately, the product was too labile to isolate in pure form. For entries 4–6, TMSBr was paired

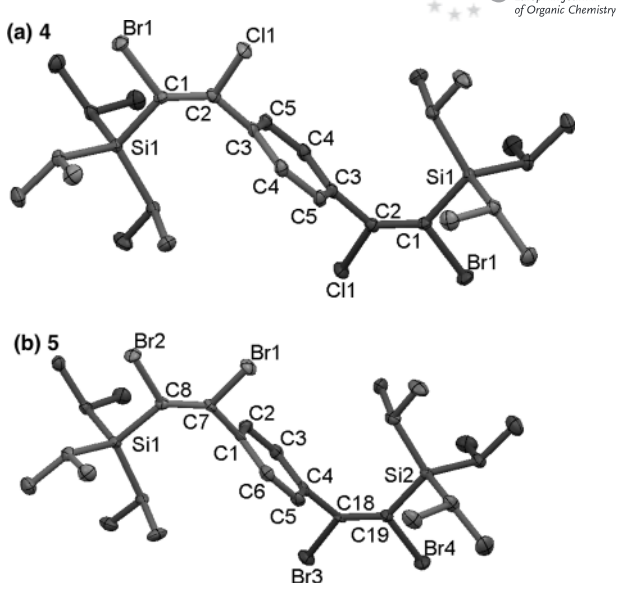


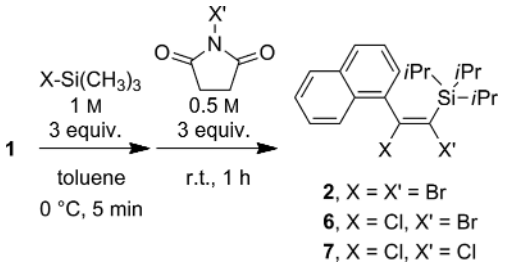
Figure 1. ORTEP drawings of **4** and **5**, with thermal ellipsoids at the 50% probability level. Hydrogen atoms are omitted for clarity. Selected bond lengths [Å] for **4** (a): C1–C2 1.341, C1–Si1 1.914, C1–Br1 1.924, C2–Cl1 1.766, C2–C3 1.488; for **5** (b): C7–C8 1.349, C8–Si1 1.921, C8–Br2= 1.933, C7–Br2 1.907, C7–C1 1.497.

with NIS, NBS, and NCS; mysteriously, each entry yielded bis-brominated **2** in up to 97% yield. For entry 7, the desired Cl–I adduct was be formed, as in entry 3, but it readily decomposed. For entry 8, finally, the combination of TMSCl/NBS resulted in high-yielding transformation to the desired vicinal hetero-dihalogenated vinyl compound, namely, Br–Cl adduct **6**. For entry 9, TMSCl/NCS also produced reasonable bis-chlorinated **7** in 75% yield along with small amounts of starting **1**. Then, as shown in Scheme 4, the importance of the reagent pairing was also investigated: no reaction was observed with only TMSBr, TMSCl, NIS, NBS, or NCS, whereas the crude product obtained with the use of TMSI decayed after workup.[21] Thus, these results imply that good pairing of the reagents is indispensable for the formation of **2**, **6**, and **7**. Noteworthy is that resultant vinyls **2**, **6**, and **7** were assembled as single isomers, and even in their crude states, isomeric mixtures were not observed by NMR spectroscopy.

As illustrated in part a of Scheme 5, the combination of TMSCl and NBS was readily amenable to gram-scale preparation of **6**, without giving any isomeric byproduct. This successful scheme implies that this pairing results in effective and formal in situ formation of BrCl, which precludes the need to handle neat BrCl. In situ produced BrCl also smoothly and selectively added to trimethylsilylalkynes to give **8** as a single spot on the TLC plate; however, the product was not tolerant to purification, and the yield decreased to 53%.[22,23] So, the TIPS group of **6** firmly served as a protecting group against decomposition, although the TMS group of **8** did not.

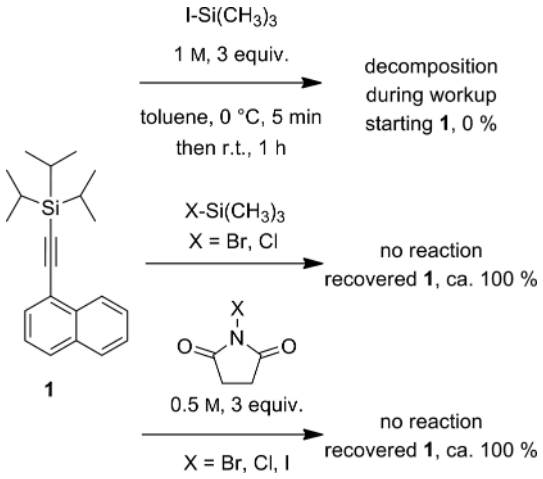
With a viable protocol in hand, the substrate scope for the bromochlorination was surveyed (Table 2). The scalable synthesis of **9** was achieved on a 10 g scale in 92% yield,

Table 1. Evaluation of the reactivity of **1** under the pairing of TMSX/NX′S.

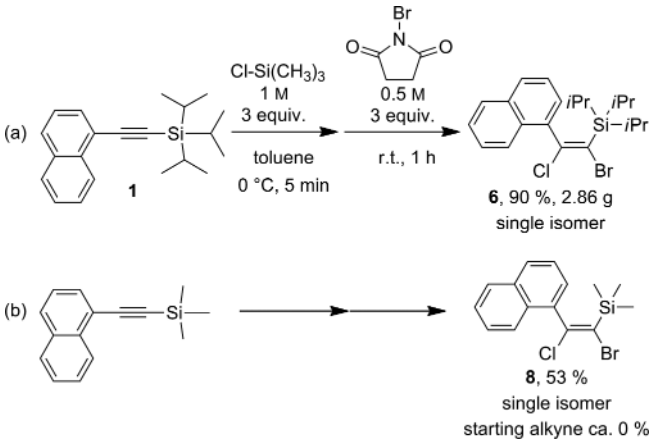


Entry	X/X′	Product	Yield [%][a]	Recovered **1** [%]
1	I/I	–	–	≈100
2	I/Br	**2**	78	15
3	I/Cl	–[b,c]	26	73
4	Br/I	**2**	97	0
5	Br/Br	**2**	85	0
6	Br/Cl	**2**	71	0
7	Cl/I	–[b,c]	63	26
8	Cl/Br	**6**	95	0
9	Cl/Cl	**7**	75	2

[a] Yield of isolated product. [b] Analysis by NMR spectroscopy suggested that the iodochlorinated adduct was formed; however, unfortunately, the product was too labile to keep in pure form. [c] Yield was calculated by ^{1}H NMR spectroscopy on the basis of its crude state, and no internal standard was used.



Scheme 4. Evaluation of the reactivity of **1** on TMSX or NXS.



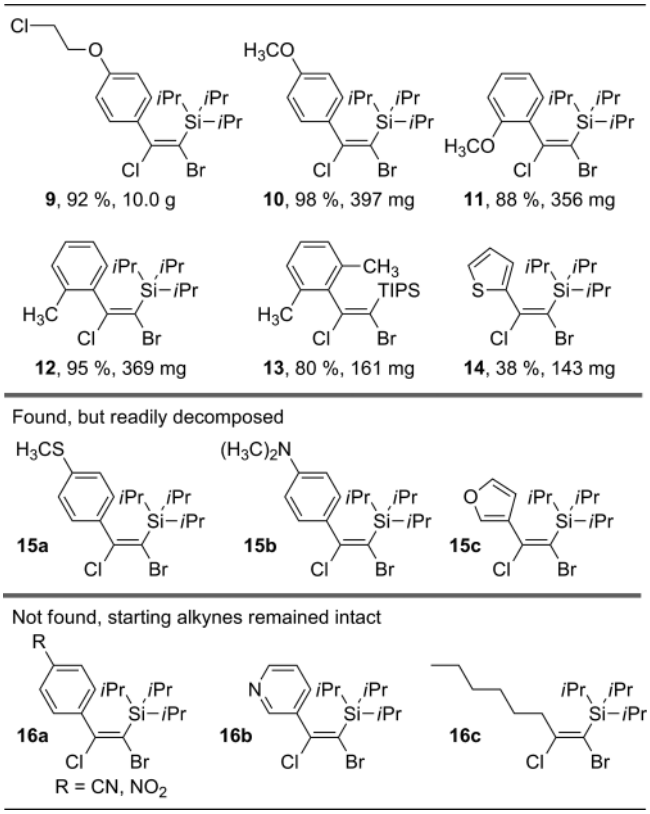
Scheme 5. Bromochlorination reaction of TIPS- and TMS-ethynyls: (a) gram-scale preparation of **6** and (b) production of labile **8**.

and *para*-methoxy **10** smoothly afforded the best yield of 98%. *ortho*-Substituted materials **11** and **12** were given in yields of 88 and 95%, respectively; more encumbered *meta*-xylyl derivative **13** was surprisingly formed in a high 80% yield as a single isomer. The yield of thiophene derivative **14** decreased to 38%; the starting alkyne disappeared, and multiple spots were observed on the TLC plate of the reaction. Although for reasons we are not certain of at this time, we were unable to prepare olefins **15** and **16**. Compounds **15a**–**c** endowed with electron-donating groups were formed during the course of the reaction; however, these immediately decomposed after purification by silica gel column chromatography and the resulting compounds could not be identified through their physical data.[24] On the other hand, **16a** and **16b** bearing electron-withdrawing aryl groups as well as hexyl-substituted **16c** were not formed, because the corresponding starting alkynes remained intact. These results indicate that the product distribution was affected by differences in the electronic character of the triple bond; in situ BrCl might take appropriate electron density by adding to the bond, and the resulting olefins would not be a robust substructure.

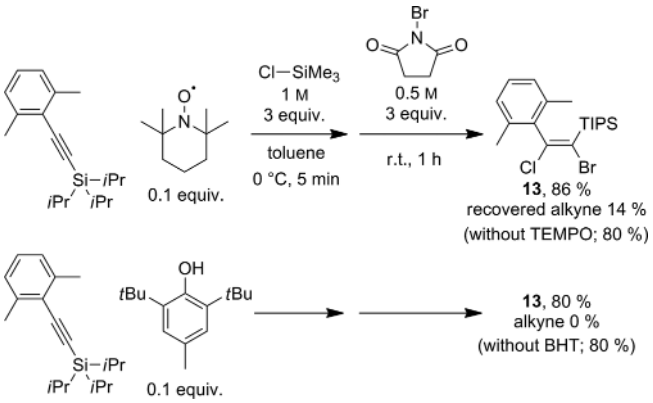
What kind of reaction process controls the selective bishalogenation? Is this a radical process? The addition of TEMPO [(2,2,6,6-tetramethylpiperidin-1-yl)oxidanyl] and BHT (butylhydroxytoluene) as scavengers was tested for the reaction in which the TMSCl/NBS system yielded **13** in 80% yield (Scheme 6). The employment of TEMPO and BHT afforded **13** in yields of 86 and 80%, respectively. Both reactions proceeded cleanly by TLC monitoring without giving any byproduct. This result suggests that a radical mechanism is unlikely.

Taking into account that a nonradical process occurs, we performed the synthesis of **10** in which TIPSCl/NBS was used instead of TMSCl/NBS (Scheme 7). TIPSCl lowered the yield to only 10% compared to 98% in the case of TMSCl. Clearly, the more congested TIPSCl would disrupt the reaction progress; so, the ^{1}H NMR spectra of both TMSCl/NBS and TIPSCl/NBS were acquired and monitored over the course of the reaction (Figures 2 and 3).[25] Figure 2 shows a new signal indicated by a dot at δ = 2.68 ppm, and this signal increased in intensity and ultimately was greater in intensity than the original NBS signal. The new resonance corresponds to CH_2 of the resultant *N*-TMS-succinimide,[26] and the molar ratio of NBS/*N*-TMS-succinimide over the 60 min period was calculated from the integrated values as 18:82. This explains that in situ BrCl was also produced in about 82% yield.[27] On the other hand, Figure 3 illustrates a new resonance indicated by a dot at δ= 2.66 ppm, and this signal remained smaller than the original NBS signal for 60 min. This new resonance cor-

Table 2. Substrate scope.[a]

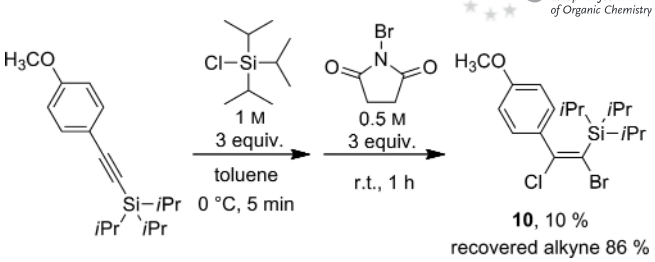


[a] The stereochemistry of **9**–**14** was inferred from evidence of the two ORTEP drawings in Figure 1.



Scheme 6. Bromochlorination in the presence of TEMPO and BHT.

responds to CH_2 of the resultant *N*-TIPS-succinimide, and the molar ratio of NBS/*N*-TIPS-succinimide in the 60 min period was calculated to be 60:40. This shows that in situ BrCl was formed in about 40% yield, that is, TMSCl/NBS had better generative efficacy of in situ BrCl than TIPSCl/NBS, because the periphery of the silicon atom in TMSCl is less crowded than that in TIPSCl for the interaction of the nitrogen atom in the succinimide.



Scheme 7. TIPSCl-mediated bromochlorination.

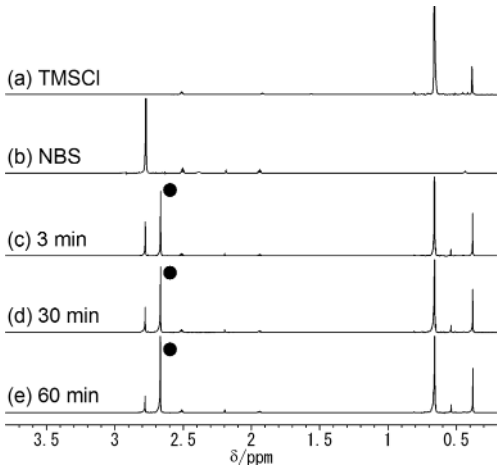


Figure 2. Reaction of TMSCl (13 mg, 0.12 mmol) with NBS (21 mg, 0.12 mmol). Portions of the ^{1}H NMR spectra between 0.2 and 3.8 ppm (400 MHz, 300 K, 0.3 mL of C_7D_8 and 0.2 mL of CD_3CN) of (a) TMSCl, (b) NBS, and (c–e) the reaction process (3, 30, 60 min) obtained upon addition of NBS (0.6 M in CD_3CN) to a 0.4 M solution of TMSCl in C_7D_8. The signals labeled with dots are new.

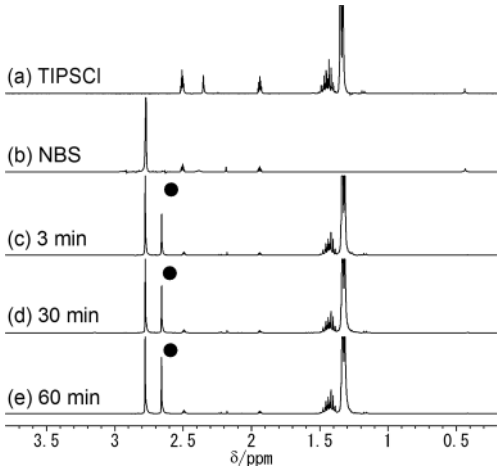


Figure 3. Reaction of TIPSCl (23 mg, 0.12 mmol) with NBS (21 mg, 0.12 mmol). Portions of the ^{1}H NMR spectra between 0.2 and 3.8 ppm (400 MHz, 300 K, 0.3 mL of C_7D_8 and 0.2 mL of CD_3CN) of (a) TIPSCl, (b) NBS, and (c–e) the reaction process (3, 30, 60 min) obtained upon addition of NBS (0.6 M in CD_3CN) to a 0.4 M solution of TMSCl in C_7D_8. The signals labeled with dots are new.

The mechanism resulting in high stereochemical control to produce predominantly (*Z*) adducts is not yet fully

known. Preliminary mechanistic investigations were performed through the substrate scope in Table 2. The preparation of **16a** and **16b** having electron-deficient groups was a complete failure, although reactions with aromatic substrates endowed with electron-donating groups as well as congested substituents succeeded with perfect selectivities. We envisage that the bromochlorination follows a concerted pathway, not a stepwise path:[28] the nucleophilic triple bond initially attacks the Br atom, and simultaneously a Cl atom bonds to the benzyl carbon atom in a *syn* mode.

Conclusions

In summary, highly regio- and stereoselective synthesis of vicinal (*Z*)-dihaloalkenylsilanes from silyl ethynylarenes was achieved by utilizing in situ BrCl, Br_2, and Cl_2. The in situ halogens were readily generated by reaction of halotrimethylsilane with *N*-halosuccinimide,[29] which then perfectly added to the triple bond in a *syn* mode. The resultant dihaloalkenylsilanes were elegantly formed as single isomers. This simple and reliable protocol is particularly valuable to synthesize selective bromochlorinated vinyls, because neat BrCl is a difficult-to-handle reagent owing to its low boiling point of 5 °C. Development of this methodology to selective halosilylation of internal alkynes is ongoing for the synthesis of differently all-carbon tetrasubstituted olefins.

Experimental Section

Representative Procedure for Synthesis of (*Z*)-[1-Bromo-2-chloro-2-(naphthalen-1-yl)vinyl]triisopropylsilane (6): Under an argon atmosphere, TMSCl (1 M in CH_2Cl_2, 0.75 mL) was added dropwise over 5 min to a solution of **1**[30] (154 mg, 0.5 mmol) in anhydrous toluene (2 mL) at 0 °C, and the mixture was stirred for 5 min. Then, NBS (134 mg, 0.75 mmol) in acetonitrile was slowly added over 5 min, and the ice-bath was removed to warm to room temperature. After additional stirring for 1 h, the reaction was quenched at 0 °C with saturated aqueous sodium thiosulfate ($Na_2S_2O_3$), and the mixture was stirred for 10 min and then warmed to ambient temperature. The aqueous phase was extracted with toluene (3 × 10 mL). The combined organic phase was washed with brine (15 mL), dried with sodium sulfate, and concentrated to give the crude product (244 mg). Purification by short-plug column chromatography (hexane) afforded **6** (205 mg, 95%) as a white solid material. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.01 (d, *J* = 8.3 Hz, 1 H), 7.87 (d, *J* = 8.8 Hz, 1 H), 7.85 (d, *J* = 8.8 Hz, 1 H), 7.57–7.26 (m, 4 H), 0.97 (d, *J* = 6.5 Hz, 9 H), 0.90 (sept, *J* = 6.5 Hz, 3 H), 0.76 (d, *J* = 6.5 Hz, 9 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 141.2, 136.1, 133.5, 131.2, 130.1, 128.6, 128.3, 127.4, 126.8, 126.4, 125.9, 124.7, 18.9, 18.6, 12.5 ppm. IR (neat): ν̃ = 2942, 1863, 1556, 1505, 1461, 1389 cm^{-1}. MS (EI): *m*/*z* = 422 [M]$^+$. HRMS (DI): calcd. for $C_{21}H_{28}BrClSi$ 422.0832; found 422.0820.

Supporting Information (see footnote on the first page of this article): Characterization data and ^{1}H NMR and ^{13}C NMR spectra of all new compounds.

Acknowledgments

The authors thank Professor Kiyosei Takasu, Professor Ken-ichi Yamada, and Professor Yosuke Yamaoka at Kyoto University for assistance with measurement of the X-ray diffraction and scattering data. Dr. Toshiyuki Iwai and Dr. Takatoshi Ito at OMTRI are gratefully thanked for assistance with HRMS.

[1] a) L. Brandsma, H. Verkruijsse, *Preparative Polar Organometallic Chemistry 1*, Springer, Berlin, **1987**; b) B. J. Wakefield, *Organolithium Methods*; Academic Press, London, **1988**; c) L. Brandsma, *Preparative Polar Organometallic Chemistry 2*, Springer, Berlin, **1990**; d) M. Schlosser, *Organometallics in Synthesis A Manual* (Ed.: M. Schlosser), 2nd ed., Wiley, Chichester, UK, **2002**, p. 1–352.

[2] a) M. A. Brook, *Silicon in Organic, Organometallic, and Polymer Chemistry*, Wiley, Chichester, UK, **2000**; b) I. Fleming, A. Barbero, D. Walter, *Chem. Rev.* **1997**, *97*, 2063–2192; c) I. Fleming, J. Dunogus, R. Smithers, *Organic Reactions*, Wiley, New York, **2004**, p. 57–575; d) E. W. Colvin, *Silicon Reagents in Organic Synthesis* Academic, London, **1988**; e) W. P. Weber, *Silicon Reagents for Organic Synthesis* Springer, Berlin, **1983**; f) E. W. Colvin, *Silicon in Organic Synthesis* Butterworth, London, **1981**.

[3] a) H. Neumann, D. Seebach, *Chem. Ber.* **1978**, *111*, 2785; b) D. A. Evans, T. C. Crawford, R. C. Thomas, J. A. Walker, *J. Org. Chem.* **1976**, *41*, 3947.

[4] a) J. Ruan, J. Xiao, *Acc. Chem. Res.* **2011**, *44*, 614–626; b) D. Ma, Q. Cai, *Acc. Chem. Res.* **2008**, *41*, 1450–1460; c) A. F. Littke, C. Dai, G. C. Fu, *J. Am. Chem. Soc.* **2000**, *122*, 4020–4028; d) N. Miyaura, *Advances in Metal-Organic Chemistry* (Ed.: L. S. Liebeskind), JAI, London, **1998**, vol. 6, p. 187–243; e) N. Miyaura, A. Suzuki, *Chem. Rev.* **1995**, *95*, 2457–2483.

[5] a) Y. Nakao, T. Hiyama, *Chem. Soc. Rev.* **2011**, *40*, 4893–4901; b) S. E. Denmark, J. H.-C. Liu, *Angew. Chem. Int. Ed.* **2010**, *49*, 2978–2986; *Angew. Chem.* **2010**, *122*, 3040–3049.

[6] a) A. Dondoni, A. Marra, *Eur. J. Org. Chem.* **2014**, 3955–3969; b) P. Pawluc, W. Prukala, B. Marciniec, *Eur. J. Org. Chem.* **2010**, 219–220; c) A. B. Flynn, W. W. Ogilvie, *Chem. Rev.* **2007**, *107*, 4698–4745.

[7] A. H. Sato, M. Maeda, S. Mihara, T. Iwasawa, *Tetrahedron Lett.* **2011**, *52*, 6284–6287.

[8] a) A. B. Lemay, K. S. Vulic, W. W. Ogilvie, *J. Org. Chem.* **2006**, *71*, 3615; b) M. N. Ho, A. B. Lemay, W. W. Ogilvie, *J. Org. Chem.* **2007**, *72*, 977 and references cited therein.

[9] a) M. Ide, Y. Yauchi, T. Iwasawa, *Eur. J. Org. Chem.* **2014**, 3262–3267; b) M. Ide, Y. Yauchi, R. Shiogai, *Tetrahedron* **2014**, *70*, 8532–8538.

[10] I. R. Butler, C. S. Breau, *Can. J. Chem.* **1991**, *69*, 1117–1123.

[11] O. Moatamedi, A. Semnani, A. R. Firooz, H. R. Pouretedal, M. H. Keshavarz, *Heterocycl. Commun.* **2008**, *14*, 307–318.

[12] V. L. Heasley, D. M. Buczala, A. E. Chappell, D. J. Hill, J. M. Whisenand, D. F. Shellhamer, *J. Org. Chem.* **2002**, *67*, 2183–2187.

[13] a) J. Tendli, M. Verney, R. Vessiere, *Tetrahedron* **1974**, *30*, 579; b) S. Uemura, H. Okazaki, A. Onoe, M. Okano, *J. Chem. Soc. Perkin Trans. 1* **1977**, 676; c) S. M. Hubig, W. Jung, J. K. Kochi, *J. Org. Chem.* **1994**, *59*, 6233; d) O. Bortolini, M. Bottai, C. Chiappe, V. Conte, D. Pieraccini, *Green Chem.* **2002**, *4*, 621–627; e) F. Bellina, F. Colzi, L. Mannina, R. Rossi, S. Viel, *J. Org. Chem.* **2003**, *68*, 10175–10177.

[14] a) S. C. Devito, *Chemtech* **1996**, *26*, 34; b) S. Gangolli, *The Dictionary of Substances and Their Effects*, Royal Society of Chemistry, Cambridge, UK, **1999**, p. 676.

[15] Employment of TMSBr (6 equiv.) and NIS (6 equiv.) increased the yield of **3** to 86%.

[16] a) M. Mitani, M. Masuda, A. Inoue, *Synlett* **2004**, 1227–1230; b) X. Ye, P. Wang, M. Cai, *J. Chem. Res. Synop.* **2007**, 319–322.

[17] Separate solutions of halotrimethylsilane and *N*-halosuccinimide in CH_2Cl_2 and CH_3CN, respectively, were used: the reaction efficacy was much better than if the reagent was used neat, see; A. H. Sato, S. Mihara, T. Iwasawa, *Tetrahedron Lett.* **2012**, *53*, 3585–3589.

[18] A. H. Sato, K. Ohashi, T. Iwasawa, *Tetrahedron Lett.* **2013**, *54*, 1309–1311.
[19] CCDC-1018272 (for **4**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif. Triclinic, space group $P\bar{1}$, colorless, a = 7.7593(6) Å, b = 8.0557(5) Å, c = 13.3580(9) Å, α= 88°, β= 76°, γ= 77°, V = 791.15(10) Å^3, Z = 1, T = 93 K, $d_{calcd.}$ = 1.405 g cm^{-3}, μ(Mo-K_α) = 2.822 mm^{-1}, R_1 = 0.0241, wR_2 = 0.0722, GOF = 1.110.
[20] CCDC-1027533 (for **5**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif. Triclinic, space group $P\bar{1}$, colorless, a = 7.7513(19) Å, b = 8.7277 (18) Å, c = 26.2490(6) Å, α= 90°, β= 93°, γ= 103°, V = 1618.0(7) Å^3, Z = 2, T = 93 K, $d_{calcd.}$ = 1.557 g cm^{-3}, μ(Mo-K_α) = 5.064 mm^{-1}, R_1 = 0.0425, wR_2 = 0.1580, GOF = 1.044.
[21] Decomposition could be due to trace amounts of HI that quickly forms through the reaction of TMSI with water.
[22] Any trace amounts of acid could destroy **8** on silica gel.
[23] Employment of saturated aqueous $NaHCO_3$ instead of $Na_2S_2O_3$ in the workup procedure did not always remove extra halogens and unnecessary colors of the crude products.
[24] Compounds of **8**, **15a**, and **15b** were afforded in almost pure form in the crude state; thus, they decomposed during purification. On the other hand, more than one spot accompanied the production of **14** and **15c** as the reaction proceeded; small amounts of HBr and HCl contained in NBS and TMSCl might break **14** and **15c**.
[25] Residual signals of protonated toluene and acetonitrile look small because the concentrations of TMSCl, TIPSCl, and NBS were relatively high.
[26] N. Okamoto, M. Ishikura, R. Yanada, *Org. Lett.* **2013**, *15*, 2571–2573.
[27] For entry 6 in Table 1, we do not yet fully understand why the pairing of TMSBr/NCS yielded **2**, unlike **6** in entry 8. Although the ^{1}H NMR spectrum of TMSBr/NCS was acquired, it gave ambiguous signals that were totally different from those shown in Figure 2. TMSBr/NCS might afford reactive Br_2 directly in some way.
[28] The alternative to the concerted way is a synchronous mechanism, see: a) J. Fischer, W. Steglich, *Angew. Chem. Int. Ed. Engl.* **1979**, *18*, 167; *Angew. Chem.* **1979**, *91*, 168–169; b) M. Bearpark, F. Bernardi, M. Olivucci, M. A. Robb, *J. Am. Chem. Soc.* **1990**, *112*, 1732.
[29] Very recently, interhalogens generated in situ from *N*-halosuccinimide and catalytic TMSCl were reported for aromatic halogenations, see: T. Maibunkaew, C. Thongsornkleeb, J. Tummatorn, A. Bunrit, S. Ruchirawat, *Synlett* **2014**, *25*, 1769–1775.
[30] K. Sonogashira, Y. Tohda, N. Hagihara, *Tetrahedron Lett.* **1975**, *16*, 4467–4470.

Received: November 9, 2014
Published Online: January 8, 2015

